

DICTIONARY

OF

ALPHABET



H. Adlard sculp.

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AN
EXPLANATORY
DICTIONARY
OF THE
APPARATUS AND INSTRUMENTS
EMPLOYED IN THE VARIOUS OPERATIONS
OF
PHILOSOPHICAL AND EXPERIMENTAL
CHEMISTRY.

WITH SEVENTEEN QUARTO COPPER-PLATES.

BY
A PRACTICAL CHEMIST.

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PREFACE.

Whatever system a student in Chemistry may prefer, he will often have occasion to regret, while studying that system, the insufficiency of the graphic illustrations attached to the work. In all systems of Chemistry extant, apparatus for many different purposes are referred to without being figured in the Plates ; and, although the books which do contain representations of such apparatus may, in many instances, be quoted, it too fre-

quently happens, that students, not having access to those books, are compelled to rest satisfied with mere description ; and, consequently, never acquire that full knowledge of some processes which judicious description and graphical illustration combined are calculated to impart. In attending lectures, too, a student may not have time or opportunity to examine the furniture of the lecture-table so as to be enabled perfectly to comprehend the construction and principles of every article of apparatus.

The design of the present publication is to remedy these defects, by affording representations, accompanied by suitable descriptions, of all the apparatus necessary for carrying on the multifarious operations of Philosophical Chemistry. Free use has been made of the best authorities ; information scattered through many volumes has been collected together ; many original practical remarks and explanations have been introduced ; and it is

hoped that the Work may prove an important auxiliary to every system of Chemistry, an acceptable aid to students of Chemical Science, and a useful book of reference to general enquirers.

LONDON,
October, 1824.

CHEMICAL APPARATUS.

GENERAL NATURE

OF

CHEMICAL APPARATUS AND INSTRUMENTS.

THE term chemical apparatus is applied either generally, to express the whole of the utensils and vessels that have been invented for the purpose of performing chemical experiments ; or, in a more limited sense, it is applied to those complicated instruments, for the most part of modern invention, in which a number of separate parts are combined into one whole.

Thus, according to the first application of the term, a retort is an article of chemical apparatus ; a receiver is another article ; and these two, according to the latter method of applying the term, when combined, form one of the simplest species of DISTILLATORY APPARATUS.

As chemistry is a science founded entirely on experiment and operative research, it naturally furnishes more opportunities for signalizing the inventive genius of those who successfully pursue it, than any other branch

of experimental employ ; and hence there is hardly an operator whose mind has not suggested some improvement or useful alteration in the construction of the instruments of experiment. But to the superior aid of modern instruments of research, chemistry is particularly indebted for its rapid advancement. In proof of this statement, the invention of the thermometer need only be mentioned. In the beginning of the seventeenth century, men were accustomed to judge the different degrees of heat and cold by their own feelings ; and the estimations thus formed, were often exaggerated, and always vague and fallacious. The acquisition of the thermometer first introduced certainty and precision into chemical research, and by detecting minute alterations of temperature, and changes of mutual relations, very important discoveries have been made. “ Nothing tends so much to the advancement of knowledge as the application of a new instrument. The active intellectual powers of men in different times, are not so much the causes of the different success of their labours, as the peculiar nature of the means and artificial resources in their possession.”*

Chemical Laboratory.

The place in which the operations of chemistry are carried on, is called the *Laboratory*.

It was once thought, that a building erected on purpose, and regularly fitted up with furnaces and costly apparatus, was absolutely necessary for the pursuit of experimental chemistry. This is by no means the case. The great improvements that have been made in the

* Davy's Elements of Chemical Philosophy, p. 54.

instruments of research, as well as in the art of experiment, have superseded this necessity. And although a laboratory is essential for carrying on, in the way of trade, those operations which furnish the chemical articles employed in the arts and manufactures, and in the materia medica, the philosophical chemist, whose operations afford products chiefly of value for the phenomena which they present, or the results which they exhibit, naturally endeavours to perform his processes on as small a scale as possible; for the same properties which characterise minute portions of matter, are also found in a whole mountain of the same substance. Indeed, experiments of research may always be performed with more facility on a small, than on a large scale; and a great deal of expense is saved. And in addition to this, we may apply powerful agents, and the most expensive materials, which cannot be adapted to large quantities of substances. Thus, were it not for the effect of the electrical machine, the galvanic battery, and the blow-pipe, upon minute portions of matter, a vast number of important facts, which have changed the face of chemistry within our time, would have remained undiscovered. It was by operating upon grains of matter that the nature of the diamond was established; that four new metals were detected in the ore of platina; that the composition of the stones which fall from the clouds has been determined; that the metallic basis of the alcalies has been brought to light; and that the identity of the electric agency, whether excited by the common machine, or by the pile of Volta, has been demonstrated. There is, besides, a neatness gained by operating in the closet, which is incompatible with processes carried on upon a large scale, amongst the furnaces of the regular laboratory.

In all miniature processes we are enabled to observe the gradual changes which bodies suffer during their chemical action; it is in our power to urge or to retard the operations, and to ascertain each step of the experiment from beginning to end. These advantages can be valued only by those who know that the most attentive chemist frequently meets with accidents, by which both the vessel and products of the operations are lost, because he has not the power to ascertain the nature of the results as occasion may require. It is thus also that, among the furnaces of the laboratory numerous appearances pass away unnoticed, which are readily observed when the same operation is performed in the closet under the immediate eye of the experimenter. Besides, most of those investigations which, in the large way, require several days' labour, can, on a small scale, be finished in a few hours. The heat of the most violent furnace may instantly be produced by a stream of air, passing from a blowpipe through the flame of a candle or spirit lamp. And by means of a portable furnace, the oxy-hydrogen blowpipe, and the table lamp apparatus, a vast number of chemical operations may be performed, which formerly would have required a series of complex furnaces.

The lamp furnace alone is sufficient for almost every one of the operations of chemistry in the small way, which require a temperature not exceeding a dull red heat. The processes of digestion, sublimation, the solution of earthy and metallic bodies, the concentration of liquids, all the multifarious processes of distillation by the sand-bath, and by the naked fire, the production of gases with the pneumatic apparatus, and even the fusion of earthy minerals with alcalies for analysis, may commodiously be accomplished, at a trifling expense, in the closet, with the help of this instrument. Besides, the

heat produced by the lamp-furnace has the capital advantage of being easily regulated, it may at pleasure be suppressed instantly, or maintained for several hours at a constant and determinate intensity ; and all chemists are acquainted with the extended use of the portable universal furnace ; by means of it we are enabled to perform with ease, in the closet, all those processes which demand the application of an intense heat.

I shall now proceed to give a sketch of a well-furnished laboratory, for carrying on a general course of chemical experiments.

The pursuits of philosophical chemistry may be carried on in a common apartment, either on, or above, the ground floor. A room well lighted and ventilated, and having a common fire-place, may be made to answer exceedingly well. A laboratory on the ground floor is thought by many most convenient, for the sake of water, pounding, and washing ; it certainly has these advantages, but it is also subject to great inconveniences, as constant moisture, though not very considerable and sensible, in many respects is a very great inconvenience in a chemical laboratory. In such a place, most salts and saline substances become moist in time, the gummed paper labels of bottles fall off, the bellows and many other articles rot and become mildewed, the scale-beams and metals rust, and every thing almost spoils ; a room above the ground floor is therefore preferable. The only advantage that can be derived from a ground floor is, the convenience of being easily supplied with water ; but this is not at all counterbalanced by the inconvenience of dampness. A laboratory, therefore, is more advantageously situated above than below the ground, that it may be as dry as possible. Let there be placed in the middle of the room a heavy table, or kitchen dresser, with

drawers below. This table may serve as the common place for operating with the lamp-furnace, for making preparations for processes, and in fact for all processes which do not require the intense heat of a furnace, or a forge-hearth.

In the drawers may be kept blowpipes and their appendages; thermometers; glass, silver, and platina evaporating basons; and alembics; porcelain, earthenware, and other tubes; platina, silver, and glass rods and spatulas; eudiometers; gas bottles; hydrostatic funnels; weights; cubic inch measures; small crucibles; stop-cocks; filtering paper; vials; corks; bladders; leather; packthread, &c.

The sides of the room may be fitted up with shelves, and one or more nests of drawers, such as are seen in apothecaries' shops; a cupboard with shelves will also be found extremely useful. The shelves round the room may serve to support glass, earthenware, and other vessels; the nests of drawers and cupboard are useful to preserve the products of the operations and other dry articles. In one corner of the room, if it can conveniently be done, a common stone sink should be put up, with a reservoir containing an abundance of water.

As the vessels are always cleaned in the sink, bottle brushes, wires, sticks of whalebone, sponges, towels, and a rack for draining vials, ought to be near it. In another corner may be placed a heavy solid block of wood, to serve as a support for mortars when pounding hard substances, and in which also an iron anvil may be stuck occasionally. Near this place should be hung, upon hooks, sieves of different textures, rasps, files, hammers, shears, pincers, scissars, &c. The fire-place of the room should be made as wide as possible, to receive

the portable furnaces, or a forge-hearth. Indeed, if it can be done, the opening of the chimney should extend from one wall to another; and it should be so high, that a person may easily stand under it.

The rest of the space of the chimney ought to be fitted up with one or more stands of different heights, on which small portable furnaces and other apparatus may occasionally be placed. Under the chimney, at a convenient height, should be a row of iron hooks, driven into the back and sides of the wall, upon which are to be hung hand-bellows, shovels, crucible and fire tongs, pokers, ladles, ingots, and other utensils for managing the vessels to be used with the furnaces, and for disposing the fire.

A book-case with glazed doors, to hold the nicer apparatus, such as balances, &c. and a few choice books, will likewise be highly convenient. If more than one room can be adapted for the purposes of a laboratory, it will be more advantageous to have one apartment on the ground floor and another in the upper story of the house. The first should be appropriated for the furnaces, and the performance of those processes which occasion smoke or corrosive vapours; for sifting, pounding, evaporating and other processes which make dust or fumes; and in the upper room the nicer operations, and those which require the mere heat of a lamp, should be performed. This arrangement being made, the following articles should be procured:—

*List of Instruments and Utensils, requisite for carrying
on a general Course of Chemical Experiments.*

An universal furnace, with sand-bath, muffle and various kinds of crucibles and fire tongs.

One or two table lamp furnaces.

One flat chemical lamp, and one spirit lamp.

One oxy-hydrogen blowpipe, and a common blow-pipe, with lamp, platina jets, spoon, forceps, and platina foil.

Chemical thermometers in sorts and sizes.

One or two pneumatic troughs, with an assortment of bell-glasses, cylindrical receivers, and deflagrating jars in sizes, plain and graduated.

One or two detonating tubes.

Bell-glasses, mounted with stop-cocks, bladders, &c.

An assortment of glass retorts with long necks for procuring gases.

One or two eudiometers, and small graduated glass tubes.

A series of graduated cylindrical jars, divided into cubic inches and decimal parts.

Various sized gas bottles, plain and tubulated,

Two cast iron retorts with conducting tubes.

Three or four large bladders, mounted with stop-cocks.

One or two air-holders.

An apparatus for impregnating fluids with gases.

A pneumatic mercurial trough, and a sufficient quantity of mercury.

One or two nests of cylindrical air-jars, adapted for the mercurial trough, plain and graduated.

A gazometer.

An assortment of glass and earthenware retorts, plain and tubulated, with corresponding glass receivers, also tubulated, plain, and quilled.

One or two balloon receivers.

A small copper still and refrigeratory.

One large and one small glass alembic, and one of pure silver, with glass capital.

An assortment of earthenware and black lead crucibles, round, triangular, and skittle-shaped, with corresponding stands and covers for ditto.

A specific gravity bottle.

A cubic inch bottle.

A steam bath, for drying precipitates.

One pair of delicate scales, and corresponding weights.

Two pair of common hand scales, and piles of weights for ditto.

A galvanic battery, with apparatus, for the decomposition of water, &c.

An assortment of glass, porcelain, earthen and stone ware funnels, plain and ribbed.

Three or four glass funnels, with long necks, for charging retorts.

Glass jars, in sizes, plain and with lips, for decanting or precipitating fluids.

Iron standards, with sliding rings for supporting retorts, flasks, basons, and other vessels.

A filtering stand.

Two or three filtering frames.

A series of test tubes and stand.

Earthenware basons, with spouts, in sizes.

An assortment of flasks, assay jars, matrasses, and bolt-heads.

Two or three hand-mortars of porcelain biscuit.

One or two iron hand mortars, in sizes.

A series of graduated glass measures, from 2 oz. to one pint capacity.

Florence flasks, and stands for ditto.

Various sized iron boilers and pans.

- Kitchen tea kettles, and cast-iron boilers.
Pots, and saucepans, of tinned iron.
Stoneware pipkins in sorts and sizes.
Adopters of glass and earthenware.
Steel spatulas in sizes.
Small silver and platina spatulas.
Flattened platina and silver wire.
Glass and enamel rods, for stirring acid and corrosive mixtures.
Capillary tubes, and glass rods in sizes.
Metal and glass syphons, in sizes.
A vice fixed into a heavy block.
A steel anvil and a small table anvil.
Hammers in sizes.
Flat, round, triangular, and rat-tailed files.
Ingots and casting cones.
Pincers, shears, scissars, and nippers.
Iron ladles.
Glass, silver, and earthenware spoons.
Sockets and joints, for connecting stop-cocks, &c.
Tubes of safety.
Hydrostatic funnels, for pouring liquids into air-tight vessels.
Circular pieces of metal, and plates of glass for covering deflagrating jars, &c.
Copper deflagrating ladles.
A writing diamond.
A mask, to defend the eyes against accidents in chemical operations.
Decanter and finger glasses, with lips, such as are used at table.
Wine, ale, and beer glasses.
Earthenware basons, tea-cups, and saucers.
Wide and narrow mouth vials and bottles of all sizes, plain and ground stoppered.

One or two small carboys, protected by a basket of wicker work.

Stoneware and glass jars, with tin covers.

Earthenware plates.

Hair, lawn, silk, and wire sieves.

Flannel, linen, and cotton strainers.

Tiles, slates, stone, and marble slabs.

Earthenware and porcelain tubes.

Gun-barrels and wrought-iron tubes.

Gold, silver, platina, copper, and iron wire.

Charcoal paste, for lining crucibles.

To perform more extensive and specific researches, the following articles should be ready at hand :—

A barometer.

An electrical machine and Leyden bottle.

A double-barrelled table air-pump.

A hydrostatic balance, or Nicholson's hydrometer.

A burning lens.

A mercurial gazometer.

A portable forge.

Blowpipe table, with double bellows.

A freezing apparatus.

Wollaston's reflective goniometer.

A mineralogical electrometer.

A magnetic needle and deep magnifier.

Flasks and globes, for weighing gases.

Lavoisier's calorimeter.

Leslie's differential thermometer.

Metal reflectors.

An agate and steel mortar.

An apparatus for decomposing the alcalies.

A compound distillatory apparatus.

A very delicate balance, and corresponding weights.

List of Chemical Re-agents or Tests.

Besides the before-named articles, a variety of other substances are necessary in chemical pursuits; which may be considered as instruments requisite for the practice of the science. These substances, which should be always ready at hand, are chemical re-agents or tests; they are employed in the practice of chemistry to ascertain the composition of other substances, upon which they quickly act, and produce, with them, changes sufficiently striking to the senses, from which the nature or quality of the unknown body may readily be inferred. The best chemists, at all times, have considered the study of these agents of infinite service to the successful practice of the science; because the phenomena which they produce form an assemblage of facts which have singularly added to the progress of chemical philosophy. Their practical application demands no skill nor effort of mind; they form the compass by which the chemist steers; and it may be affirmed, that he who is intimately acquainted with the general action of chemical tests, knows all that the science has to offer. To this may be added, that many useful discoveries may be made by the mere help of tests; because *a general knowledge of the composition of bodies is sufficient to direct the application of the substances of nature to useful purposes in the affairs of life.**

The most essential tests are the following.

* A Practical Treatise on the Use and Application of Chemical Tests, illustrated by Experiments, with copper plates. Third Edition, 1818.

Tests.

Red-cabbage tincture,	Muriate of tin,
Litmus tincture,	Muriate of lime,
Turmeric tincture,	Muriate of platina,
Brazil wood tincture,	Nitrate of lead,
Tincture of galls,	Nitrate of barytes,
Papers stained with these	Nitrate of silver,
tinctures,	Oxalic acid,
Alcohol,	Oxalate of ammonia,
Arsenious acid,	Potassium,
Acetate of barytes,	Prussiate of potash,
Sulphate of silver,	Prussiate of lime,
Barytic water,	Prussiate of mercury,
Hidro-sulphuret of lime,	Solution of soap in alcohol,
Lime water,	Sulphate of silver,
Acetate of lead,	Succinate of soda,
Muriate of bismuth,	Polished plates of copper,
Muriate of barytes,	iron, and zinc,
Muriate of gold,	Sulphate of iron,
Acetate of silver,	Strontia water.
Benzoat of ammonia,	Tartareous acid,
Tincture of galls,	Nitrate of mercury,
Liquid ammonia,	Phosphate of soda,
Solution of starch,	Tan,
Carbonate of ammonia,	Nitrate of cobalt,
Sulphate of soda,	Iodine.

Fluxes for the Blowpipe.

Vitrified borax,	White flux,
Vitrified phosphoric acid,	Black flux,
Dried phosphate of soda,	Crude flux,
Dried carbonate of soda,	Powdered green glass.

Salts, Saline Compounds, &c.

Carbonate of ammonia,	Nitrate of copper,
Carbonate of barytes, native,	Nitrate of lead,
Carbonate of potash,	Nitrate of potash,
Carbonate of soda,	Nitrate of mercury,
Carbonate of strontia native	Nitrate of strontia,
Muriate of ammonia,	Oxy-muriate of potash,
Muriate of lime,	Sulphate of iron,
Muriate of strontia,	Sulphate of potash,
Nitrate of ammonia,	Sulphate of magnesia,
Nitrate of barytes,	Sub-carbonate of magnesia
	Sulphate of alumine.

Oxides.

Oxide of manganese,	Black and red oxide of iron,
Red oxide of lead,	Brown oxide of copper,
Red oxide of mercury,	White oxide of tin.

Sulphurets.

Sulphuret of iron,	Sulphuret of lime,
Sulphuret of ammonia,	Sulphuret of potash.

Acids.

Sulphuric acid,	Oxy-muriatic acid, and
Nitric acid,	Mixtures of these acids and
Nitrous acid,	water in two or three dif-
Muriatic acid,	ferent known proportions

Earths.

Silex,	Barytes,
Alumine,	Strontia,
Magnesia,	Lime.

Alcalies.

Potash, soda, and solutions of these alcalies in water in different known proportions.

Metals.

Iron filings, turnings, and wire,	Silver leaf,
Copper and copper clippings,	Gold leaf,
Granulated zinc,	Tin foil and filings,
Lead foil,	Quicksilver,
	Bismuth,
	Antimony.

Miscellaneous Articles.

White marble,	Fire lutes for coating glass and earthenware retorts,
Phosphorus,	Cement for stopping cracks in iron vessels intended to bear a red heat,
Sulphuric ether,	Varnish for closely fitting bladders and bags to stop-cocks, and for rendering the joinings of small glass apparatus air-tight,
Sulphur,	
Naptha,	Fire lute to join the covers of crucibles, so as to keep them air-tight, at a strong heat,
Oil of turpentine,	Resinous cement for fixing tubes, &c. into glass vessels, to be air and water tight.
Boiled lint-seed oil,	
Spirit varnish,	
Plaster of Paris,	
Windsor loam,	
Stourbridge clay,	
Lint-seed meal,	
Common lute, for closing glass vessels, in preparing all common distilled liquors, which are not corrosive.	
Lute for confining acid and corrosive vapours,	

In every well furnished laboratory there should also be ready at hand, specimens of the most important metals, salts, oxides, and other substances not enumerated in this list. They may serve as articles of reference for private study, and other occasional purposes; and are worth preserving even as a matter of curiosity.

A person provided with such an assortment of instruments and substances, may at once perform any chemical experiment. He may perhaps occasionally be in want of a few articles of commerce, not mentioned in this list; but these may be easily procured in any situation.

Heat and Fuel.

The rays of the sun are used chiefly in the drying of vegetable substances; and the only attentions necessary, are, to expose as large a surface as possible, and to turn the substances to be dried frequently, that every part may be dried alike. They are also sometimes used for promoting spontaneous evaporation.

Alcohol, oil, tallow, wood, and turf, are occasionally employed in the laboratory.

Alcohol, oil, and melted tallow, can only be burnt on porous wicks, which draw up a portion of the fluid to be volatilized and inflamed. These inflammables are therefore burnt in lamps of various constructions. But although commonly used to produce light, they afford an uniform, but not high temperature; this may however be increased, by increasing the number and size of the wicks. Alcohol produces a steady heat, no soot, and, if strong, leaves no residuum. Oil gives a higher temperature, but on a common wick produces much

smoke and soot; these are diminished, and the light and heat increased, by making the surface of the flame bear a large proportion to the centre; which is best done by a cylindrical wick, so contrived that the air has free access both to the outside and inside of the cylinder, as in the Argand lamp. In this way, oil may be made to produce a considerable temperature, of great uniformity, and without the inconvenience of smoke.

Wicks have the inconvenience of being charred by the high temperature to which they are subjected, and becoming so clogged as to prevent the fluid from rising in them. They must then be trimmed; but this is seldom necessary with the fine oils than with the coarse.

Wood, turf, coal, charcoal, and coke, are burnt in portable and fixed furnaces. Wood has the advantage of kindling readily, but affords a very unsteady temperature, it is inconvenient from its flame, smoke, and soot, and requires much attention. The heavy and dense woods give the greatest heat, burn longest, and leave a dense charcoal.

Dry turf gives a steady heat, and does not require so much attention as wood; but it consumes fast, its smoke is copious and penetrating, and the empyreumatic smell which it imparts to every thing it comes in contact with, adheres to them with great obstinacy. The heavy turf of marshes is preferable to the light surface turf.

Coal produces most heat, but it produces also much flame and smoke.

Charcoal, especially of the dense woods, is a very convenient and excellent fuel. It burns without flame or smoke, and gives a strong, uniform, and permanent heat, which may be easily regulated, especially when it is not in too large pieces, and is a little damp. But it is costly, and burns quickly.

Coke, or charred coal, possesses similar properties with charcoal; it is less easily kindled, but is capable of producing a higher temperature, and burns more slowly. *The best fuel, for general purposes of the laboratory, is coke and charcoal mixed together; two or three parts of the former to one of the latter,* broken into pieces of the size of an egg. The light porous coke, produced in the gas light process, by means of flat horizontal retorts makes a more easily manageable fire, than the dense heavy compact coke used by the smiths, and which is prepared either in the open air, or by means of the cylindrical retorts in the gas light process. The former is more readily kindled, it requires a less draught of air, and the fire is more easily managed.

For experiments in the small way, spirit of wine is upon the whole the neatest and most convenient fuel; and hence the spirit lamp may be employed for most operations of chemistry as a very convenient mode of applying heat.

Lutes.

Lutes also form a necessary part of chemical apparatus. They are compositions of various substances, intended, 1, to close the joinings of apparatus; 2, to coat glass and other vessels; 3, to line furnaces, crucibles, &c.

Lutes of the first description are commonly employed to confine elastic vapours. They should therefore possess the following properties; 1, compactness; 2, the capability of resisting acid vapours; 3, the power of resisting a certain intensity of heat; and 4, facility of removal after the operation.

Viscid substances, as flour, starch, and gum, possess the first and last properties in a sufficient degree; they are therefore employed when the heat is moderate, and the vapour not corrosive. They are mixed with water, and spread upon slips of paper or linen, which are wrapped round the joinings of the vessels, and if necessary, secured with packthread.

Slips of bladder macerated in water, and applied with the inside next the vessels, are employed in the same circumstances; but from their great contraction on drying, they are apt to break weak vessels.

A paste, formed of almond or linseed meal and water, or mucilage, forms a very close and plastic lute, which is easily removed.

Quick-lime, reduced to powder, and well incorporated with a sixth part of muriate of soda, or with white of egg diluted with water, applied on slips of linen, dries easily, and becomes very hard. It is used for the distillation of the concentrated acids; and for that purpose burnt gypsum and water also answers very well. But these lutes must be used as soon as they are prepared, as they harden very quickly.

Chalk and oil, or glazier's putty, is a very compact lute. It becomes so hard as not to be easily removed. It is principally used for luting tubes into vessels for pneumatic purposes.

A paste of powdered tobacco pipe-clay and drying oil, or, what is still better, amber varnish, is very close, adhesive, and plastic, and is easily removed; but as it softens with heat, it must be secured by slips of linen or thread, and will not adhere to the vessels unless they are perfectly dry.

The same clay beat up with as much sand as it will bear, without losing its tenacity, with the addition of

cut tow, and a sufficient quantity of water, furnishes a very good lute, which has the advantage of resisting a considerable heat, and is applicable where the fat lute would be melted or destroyed.

Clay and sand, in the proportion of one to four, form an excellent lute, capable of resisting very high temperatures, and the greatest number of corrosive substances.

Eight parts of yellow wax melted with one of oil of turpentine, with or without the addition of some resinous substances, according to the degree of pliability and consistence required, form a very close and compact lute, through which the subtile corrosive vapours will not escape. But it is softened and liquified by heat, and therefore it cannot be used for purposes where high temperatures are required.

The lute employed for the coating of glass vessels, with the intention of making them stronger and capable of resisting violent heats, without softening, consists of four parts of sand and one of clay, made into a very thin mass, and applied in successive layers, taking care that each coat be perfectly dry before another be laid on.

In every instance where a lute is applied it is absolutely necessary to allow it to dry before the process is began; and even the fat lute, by the exposure to the air during a few days after its application, is much improved in its quality. Lutes composed of clay and sand are perfectly useless, except they be permitted to dry. In applying a lute, the part immediately over the junction of the vessel should swell outwards, and its diameter should be gradually diminished at each side.

The junctures of vessels which are to be luted to each other must previously be accurately and firmly fitted by introducing between them, when necessary, short bits of wood or cork, or if the disproportion be very

great, by means of a cork fitted to the one vessel, having a circular hole bored through it, through which the neck of the other vessel or tube passes.

After being thus fitted, the lute is rolled and worked between the fingers till it be softened, and is then formed into small cylinders, which are successively applied to the junctures, taking care that each piece be made to adhere firmly and perfectly close in every part before another is put on. Lastly, the whole is secured by slips of linen or bladder.

In many cases to permit the escape of elastic vapours, a small hole is made through the lute with a pin, or the lute is perforated by a small quill fitted with a stopper. This, however, is seldom necessary.

General Observations on the Method of conducting Chemical Experiments.

As chemistry is an experimental science it must be obvious to every one, that the knowledge of its facts is founded on practical research. And hence we cannot hope to pursue the study of chemistry with advantage, without performing such processes as verify most of the capital generalities of the science, and also such as reasoning, analogy, and a laudable desire of experimenting, never fail to suggest to those whose taste and talents lead them that way. In the most common operations of experimental chemistry, a vast number of small facts occur, not mentioned in books, but which are essential to be known, for if they were described as often as they present themselves in practice, a great loss of time would follow. They are too numerous and too minute, and no advantage would be

gained in perspicuity; and the knowledge of these particulars can only be acquired by practice, and not from books or other means—the chemist teaches himself!—*Ipse sibi tradit spectator.*

To give success to operative research, the following general advice of Macquer and Dr. William Henry, is truly valuable:—In the performance of chemical experiments great attention is necessary to neatness and order. Let every jar or bottle of the laboratory have a label affixed to it, expressing the substance it may contain, except in cases where the nature of the contents is evident from mere inspection. Let the date and object of the experiment be regularly entered into a book kept for that purpose; such a proceeding will enable the operator to form a habit of accurate observation, and will tend also to facilitate the acquirement of the art of describing chemical phenomena, with precision, to do which, with selection and facility, is far from being an universal talent.

Method, attention, order, and cleanliness are essentially necessary in chemical pursuits. Every vessel and utensil ought to be well cleansed as often as it is used, and when no longer required, put again in its proper place. These cares, which seem to be trifling, are certainly very fatiguing and tedious, but they are very important, though frequently little observed.

Let the operator not engage in many different experiments at once, the consequences of which are that the attention is distracted, and many interesting appearances pass unnoticed.

When a person is keenly engaged, experiments succeed each other quickly; some seem nearly to decide

the matter, and others suggest new ideas; he cannot but proceed to them immediately, and he is led from one to another; he thinks he shall easily know again the products of the first experiment, and therefore he does not take time to put them in order; he prosecutes with eagerness the experiments he has last thought of, and in the mean time the vessels employed, the glasses and bottles filled, so accumulate, that he cannot any longer distinguish them, or at least he is uncertain concerning many of his former pursuits. This evil is increased if a new series of operations succeed and occupy all the laboratory; or if he be obliged to quit it for some time, every thing then goes into confusion. Hence it frequently happens, that he loses the fruits of much labour, and that he must throw away almost all the products of his experiments.

The only method of avoiding these inconveniences is to employ the cares and attentions above mentioned. It is indeed disagreeable to stop continually in the middle of the most interesting researches, and to employ time that appears very precious and considerable, in cleaning vessels, arranging them, fastening labels on them, &c. These employments are capable of cooling or retarding the progress of genius, and are tedious and disgusting; but they are nevertheless necessary. Those persons, whose fortune enables them to have an assistant operator, on whose exactness and intelligence they can depend, avoid many of such disagreeable circumstances; but they ought nevertheless to attend to the execution of these things. We cannot depend too much on ourselves in these matters, however minute, on account of their consequences. This becomes even indispensable when the experiments are to be kept secret, at least for a time; which is often necessary in chemical pursuits.

When new researches and inquiries are made, the mixtures, results, and products of all the operations ought to be kept a long while, distinctly labelled and registered ; for these things, when kept some time, frequently present phenomena, that were not at all suspected. Many fine discoveries in chemistry have been made in this manner ; and many have certainly been lost by throwing away too hastily or neglecting the products.

It cannot be too much recommended to chemical operators, to be exceedingly upon their guard against imposing and deceitful experiments, which sometimes present themselves in practice. A circumstance seemingly unimportant, or not easily perceptible, is frequently sufficient to give the appearance of a great discovery, by means of certain effects, which, nevertheless, are found to proceed from some other cause. This is a common error which is often committed by those who have hastily studied the science. Chemical experiments depend on so many accessory things, that all of them can seldom be attended to, particularly when the subject is new : hence we frequently find that very different results proceed from the same experiments, and at different times. We therefore must not decide after the first success ; but the experiment must be repeated several times, and even varied, till no doubt can remain. In all conclusions deduced from experiments, the utmost caution and the strictest self inquiry ought therefore to be practised. Impelled by vanity and a blameable ambition of invention and discovery, many persuade themselves of having observed facts such as besides themselves nobody divested of prejudice is able to perceive. Every fact must be compared with the most scrupulous accuracy, and not a single or solitary result alone ; but the whole, and other results produced under a variety of

circumstances arranged on purpose, should be considered before a conclusion is advanced.

Since chemistry offers views for the improvement of the arts; as it presents prospects of many useful and profitable discoveries; those who apply their labours in this way ought to be exceedingly circumspect, not to be led into an useless expence of money and time. The folly and subsequent distress of pursuing experiments in chemistry, for the sole purpose of commercial advantage, by the chemical philosophers, has been repeatedly observed both by public writers and in private life. For although it is admitted, that speculation and discovery belongs to the province of the man of science, although his ardour in the pursuit of truth may be unremitted; yet his intellectual habits and situation in society are seldom such as may be calculated to produce beneficial advantages. Detached as he usually is from the ordinary pursuits of society, little, if at all, accustomed to contemplate the scheme of traffic, of profit and loss, he can seldom descend from the sublime contemplations which escape the vulgar mind, and enter into the complex system of trade, of weight, measure, price, quality, barter or exchange, with innumerable other circumstances and arrangements, which must be known, in all its bearings, before a chance of success can be gained. Does he know them? will he become a tradesman or manufacturer? or can he expect advantages and profit if he do not? are his resources and his power equal to his task?—surely they are not. The practical advantages, the stimulus of interest, the capital of the manufacturer, are usually wanting under such circumstances.

By these reflections we do not intend to divert from all such researches those whose taste and talents render

them fit for them; on the contrary, we acknowledge, that the improvement of the arts, and the discovery of new objects of manufacture and commerce, are undoubtedly the finest and most interesting part of chemistry, and which make that science truly valuable; for without these ends what would chemistry be but a science purely theoretical, and capable of employing only some abstract and speculative minds, but useless to society. Indeed we acknowledge also, that the successes in this kind of chemical inquiry are not rare; and that their authors have sometimes acquired fortunes, so much the more honourable as being the fruits of their talents and industry. But we repeat, that, in these researches, the more dazzling, the more valuable and near any success appears, the more circumspection, and even distrust, is necessary. Chemistry is full of imposing processes, which serve only to flatter the imagination and deceive the unwary, and which lead to expense before their fallacy is discovered.

CHEMICAL

APPARATUS AND INSTRUMENTS.



ACID HOLDER, fig. 38. plate I.—This name is given to a glass bottle *a*, furnished with a glass stop-cock, fitted air tight by grinding into the tubulure of a retort, or other vessel. Its use is to convey a liquid into a retort or apparatus, to which it has been previously adapted, without admitting the external air into the vessel, or suffering the gas within to escape out of the vessel. It is either plain or tubulated. Fig. 29, plate I. *a* is a tubulated acid holder fitted to a common gas bottle *b*. This contrivance is very useful for procuring gases, without the possibility of their escaping into the room during the process, a circumstance which is of considerable importance, when the gas has an unpleasant smell or deleterious properties. Suppose that sulphuretted hydrogen gas is to be obtained from sulphuret of iron and diluted sulphuric acid; the sulphuret of iron, in coarse powder, is put into the body of the gas bottle fig. 29. plate I. with a proper quantity of water. The acid holder, *a*, is filled with the diluted acid, the cock *c* being shut, and is then fixed into the tubulure of the gas bottle, to which it is accurately adapted by grinding. The bent tube *d* being made to terminate under a receiver filled with and inverted in water, the perforated

cock is gradually opened, in consequence of which the acid descends into the gas bottle *b*, and acts on the sulphuret of iron. If it be found necessary to renew the acid, without disturbing the apparatus, this may be done as follows. The cock being shut, the stopper, which closes the tubulated acid holder, may be removed, and fresh acid poured in, through the aperture. This may be repeated as often as is found necessary. The acid holder may also be advantageously adapted to a retort, see fig. 38. plate I. for certain distillations, such as that of muriatic acid, &c.

If the acid holder, is not tubulated, fig. 38, plate I. the flow of the acid cannot be regulated at pleasure, on account of the contents of the bottle *a* having no communication with the external air. This inconvenience is remedied in fig 29, plate I. where by loosening the stopper the liquid flows freely from the bottle.

The size of the acid holder is usually from six to ten cubic inches capacity.

ADOPTER, fig. 8, plate I.—A spindle shaped, or sometimes conical, tube, commonly made of earthenware or glass. The adopter, is used for elongating the neck of a retort, in order to facilitate in the process of distillation the condensation of the vapours, by removing the receiver farther away from the source of heat; the wider extremity *a, a*, of the adopter is slipped over the neck of the retort, whilst the narrow end is inserted into the mouth of the receiver. The extremity of the adopter is made sometimes curved, as shown fig. 6. plate IX. Fig. 9, plate XII. shows the application of an adopter; *a* is the adopter. Fig. 1, plate IX. *a, a, a*, are spindle shaped adopters

AIR FUNNEL, (READ's), fig. 1. plate XI.—*i* is a funnel with its pipe or tube stopped at *b*, and perforated above and below with two or three small holes. Round the tube *a* is soldered the tube *d*, left open at top. The tube *g* is made to circumscribe the tube *d*, and is soldered to the funnel *i*.

When water is poured into the funnel, and the cork *k* inserted into a bottle filled with gas, the water descends through the tube *a* till it arrives at the division of section *b*; it then flows through the small holes at *c*, and ascends between the tubes *a* and *b*, flows over the top of *d*, and descends again between the tube *d* and *g*, till it arrives at *e* (whence it re-enters the tube through an opening above *e*), and thence into the bottle. As the water goes in, the air escapes between the tubes *a* and *g*, through the cock *h*, into the mouth-piece. The lower end of *g* is made to perforate a cork, which is properly attached to it, and which secures it air-tight into the neck of a common bottle.

AIR FURNACE, fig. 13. plate XV.—This furnace was invented by Mr. Knight; it is an air furnace with an additional chamber, for applying the waste heat to useful purposes. *a* the internal cavity, which is square, for containing the fuel and the crucible. *b* the flue passing into a hot chamber *c*; an appendage particularly useful for drying luted crucibles, or bringing them to a proper temperature for the furnace, for roasting ores, and various other purposes. *d* the flue connecting it with the vertical chimney *e*; which, to produce a strong heat, should never be less than thirty or forty feet high. *ff* covers, consisting of twelve-inch Welch tiles, with handles. *g* the stoke hole, through which no more of the fire is seen than appears between the grate and the

bearing bar *h*. This space is left for the double purpose of raking the fire, and occasionally taking out the bars. *k* the ash pit, which is sunk below the level of the ground, and is covered, where it projects at *l*, by an iron grating.

The best situation for this furnace is an angle of the laboratory, the chimney being in the corner, as represented in the sketch. By this arrangement, the operator is spared the disagreeable necessity of scorching his legs, by standing opposite the stoke hole, while the back of his legs are exposed to a current of cold air rushing to the furnace.

AIR FURNACE, (CHEVIX's), fig. 10. plate V.— The great advantage of this air furnace is, that it permits the fuel to descend without the help of stirring. The sides of the furnace instead of being perpendicular as usual, are in this furnace inverted, so that the hollow space is pyramidal. At the bottom the opening is thirteen inches square, and at the top but eight. The perpendicular height is 17 inches. This form appears to unite the following advantages. 1st. A great surface is exposed to the air; which, having an easy entrance, rushes through the fuel with great rapidity. 2nd. The inclined sides act, in some measures, as reverberating surfaces: and 3rd. The fuel falls of itself, and is always in close contact with the crucible, placed near the grate. This is the principal advantage. It is inconvenient and dangerous for the crucible to stir the fire often to make the fuel fall, and the pyramidal form renders this unnecessary. It is also more easy to avoid a sudden bend in the chimney by the upper part of the furnace advancing as in this construction. *a* is a grate; *c* and *c* are two bricks, which can be let in at pleasure

to diminish the capacity; *b* is another grate, which can be placed upon the bricks *c* and *c* for smaller purposes; *d* and *d* are bricks which can be placed upon the grate *b* to diminish the upper capacity, so that in fact we have four different sizes in the same furnace. The bricks must all be ground down to the slope of the furnace and fit in with tolerable accuracy. They are totally independent of the pyramidal form, &c. of the furnace.

AIR HOLDER (WATTS'S), fig. 16. plate XI.—This is one of the most useful machines of the laboratory. It is employed for collecting and preserving large quantities of gases, or for transferring them into bladders or other vessels. The air-holder consists of a cylindrical vessel *a*, made of sheet iron, japanned within and without. In the centre of it is a metal pipe *b*, one extremity of this pipe descends within half an inch of the bottom of the vessel *a*, or below the projecting tube *d*, and the other extremity passes through the middle of the top, or cover, as shown in the design. To charge this gas holder with a gaseous fluid, close the small projecting tube *d*, with a cork, and also the opening *f*. Having done this, fill the air-holder completely, by pouring water into the tube *b*. This being done, close the stop-cocks *f*, and then withdraw the cork which closed the aperture *d*. It is now obvious that no water can run out till air be introduced to expel it; when it is therefore wished to be filled, let the neck of the retort, or gas bottle, or other apparatus, from whence the air proceeds, be loosely inserted into the orifice of the tube *d*; the gas, as it is disengaged, will dispel the water by the same aperture, till the gas holder be completely filled with gas. If the orifice of the tube *d*, be now

corked, the gas may be preserved for any length of time. To transfer any portion of the gas from the air holder, affix a bladder, fig. 15. plate XI. to the stop-cock *f*, and pour water into the opening *b*, and the gas will arise through the cock *f*, into the bladder; the bladder is mounted with a stop-cock, and connecting piece, to fit the stop-cock *f* of the air holder.

AIR HOLDER (CAVALLO'S), fig. 10, plate XI.—The vessel *a* may be a glass jar or bottle; *b*, a funnel, into which is fastened a bent glass tube *c*; *d* is a tube, furnished with a stop cock, soldered to the funnel, and which with it passes through the cork of the vessel *a*; *b* represents a tube of tin, or other material, to one end of which a mouth-piece, or bladder, or oiled silk bag, may be fastened.

The vessel *a* being filled with the required gas, by taking out the cork with the funnel, &c. filling the vessel with water, and inverting it with its opening under water. Then, if a tube leading from the apparatus whence the gas is produced, be brought under the mouth of the vessel, the gas will ascend and displace the water till it be full. Whenever it may be necessary to transfer any quantity of the gas into a bottle, bladder, &c. an equal quantity of water is to be poured through the funnel *b*, which will displace the gas, and force it through the pipe *e*, when the stop-cock is opened.

The bent part of the tube *c*, by always containing some water, prevents the gas from escaping through the funnel; but when the apparatus is to be set by, both the funnel, and stop-cock of the tube, must be closed.

AIR JAR, figs. 23, 24, plate IV.—Air jars are called such glass receivers, of various kind, as are used in the

pneumatic trough, for collecting transferring, and preserving gases, they are either closed and vaulted at top, *a* fig. 16, 18, plate II. ; and figs. 23, 24, plate IV. :—or open, fig. 12, plate IX. ; and fig. 22, plate IV. :—or furnished with a short wide neck, fig. 21, plate IV. ; and fig. 7, plate XII. The former are usually called bell glasses, the latter are called deflagrating jars. The margin of the open necks of deflagrating jars should be ground smooth so that when a piece of ground glass or metal, or a piece of pasteboard, is pressed upon it, the gas may be confined within the jar.

The chemical operator should be provided with an assortment of air jars in sizes. He should have some mounted with stop-cocks, *a* fig. 47, and fig. 50, plate I. for transferring gases from the jars into bladders, flasks, or other vessels. Others should be graduated into cubic inches, or equal parts, fig. 2, plate I.

When trial is to be made of any kind of air whether it be fit for maintaining combustion, the air is put in a long narrow glass vessel, whose mouth being carefully covered, may be turned upward; a piece of wax candle being then fastened to the end of a wire, which is bended so that the flame of the candle may be uppermost, when introduced into the vessel. See fig. 12, plate IX. and fig. 22, plate IV.

AIR THERMOMETER, fig. 3, plate IV.—This instrument is simply a hollow glass ball *a*, from $\frac{1}{2}$ an inch to 1 $\frac{1}{4}$ inch in diameter, from which a cylindrical tube *b*, twelve or eighteen inches long, and about $\frac{1}{16}$ of an inch in the bore, issues. To use this instrument, a small quantity of the air of the tube is expelled, by applying heat to the ball. The open end is then immersed in quicksilver or any coloured liquor, and as it cools, a quantity

of the fluid rises in the tube *b*. A scale of equal parts is applied to the tube, and the extent of the expansion of air in the bulb, by heat, is accurately discovered by the descent of the coloured liquor, its condensation by cold being marked by its ascent. This instrument has the advantage of indicating very minute changes of temperature, air being so greatly altered in its volume by alterations of temperature, and on this account it may be occasionally used with advantage for some purposes. It is otherwise an inaccurate instrument, liable to variations, from changes in the pressure of the atmosphere, and inapplicable to the measurement of any extensive range of temperature.

The expansion of air by the same degrees of heat differs according to its density, and to the quantity of moisture it contains; nor are the increments of its bulk proportional to the degrees of temperature.

AIR THERMOMETER FOR LIQUIDS, figs. 4 and 5, plate IV.—This instrument is intended for the purpose of ascertaining the temperature of liquids. It consists of a bottle *a*, partly filled with any coloured liquid, and partly with air, a glass tube of small bore, open at both ends, being either cemented or hermetically sealed in the bottle, so that its lower extremity may nearly touch the bottom of the bottle. The expansion of the included air, on the application of heat, drives the coloured liquid up the tube.

ALCALI DECOMPOSING APPARATUS, fig. 3, plate X.—This name has been given to a contrivance for obtaining the alkaline metals, potassium and sodium. * It consists of a common gun-barrel curved,

* Henry's Chemistry, Vol. 1. page 214.

and drawn out, at one end, to rather a smaller diameter. To one end is adapted an iron tube *a*, of the capacity of two cubic inches, for containing the potash. At the bottom of this tube is a small hole, through which the potash gradually flows. To the opposite end of the gun-barrel a tube of safety *e* is to be cemented; and into this a sufficient quantity either of mercury or naphtha is poured. Into the gun-barrel $2\frac{1}{2}$ parts of very clean iron turnings are to be introduced, and pushed on to the bent part *c*. The tube, carefully luted, is then to be placed in a small crucible furnace *d*, nine or ten inches in diameter, and provided with a pair of double blast bellows, the pipe of which is shewn at *f*. The next step is to insert the tube *a* in its place, after having put into it $1\frac{3}{4}$ parts of pure potash, deprived of as much water as possible by previous fusion. The whole apparatus should be perfectly dry, clean, and impervious to air.

A strong heat is now to be excited in the furnace *d*; and while this is doing, the tube containing the potash, as well as the opposite end of the barrel, should be kept cool by ice. When the barrel has attained a white heat, the potash in *a* may be melted by a small portable furnace. It will flow, through the small hole, upon the iron turnings at *c*. A considerable quantity of hydrogen gas will be evolved by the decomposition of that portion of water which the potash retains even after fusion. When the production of this gas slackens, we may remove the small furnace from beneath the tube *a*, and increase the heat in the furnace *d*, in order to restore to the iron turnings at *c* the temperature proper for decomposing more potash. These operations may be repeated, alternately, till no more gas is produced; but last of all, the heat in the furnace should be strongly raised, in order to drive off some of the potassium, which strongly adheres to the iron turnings.

When the furnace is quite cold, the safety tube *e* is to be removed, and its place supplied by an iron plug. If the end of the gun-barrel, projecting from this side of the furnace, has been kept carefully cooled during the experiment, the potassium will be found adhering to it, in the form of brilliant laminæ. In order to extract it, the gun-barrel is to be cut at the commencement of the part which has been kept cool, where the greatest quantity will be found. Another portion will be found close to the plug, and this adheres so slightly to the gun-barrel, that the least effort serves to detach it. It is even partly oxidized by the air, which gains access during the cooling of the furnace; and when the whole is covered with naphtha, the oxidized part is detached in laminæ, exposing a white brilliant metallic surface. The potassium which is condensed nearest the furnace must be detached by a sharp chissel, and in the largest pieces we can possibly break off; for if it be in small molecules, it inflames in the air, even at very low temperatures. In the middle of the gun-barrel we find an amalgam of potassium and iron, which becomes green on exposure to the air, the potassium returning to the state of potash.

When the iron turnings are very clean, the potash dry and pure, and the whole apparatus free from foreign matters, the metal produced differs very little from that obtained by a Voltaic battery. Its lustre, ductility, and malleability are similar. Its point of fusion and specific gravity, however, is a little higher; for it requires nearly 130° Fahrenheit, to render it perfectly fluid, and is to water as 796 to 1000 at 60° Fahrenheit. This Sir H. Davy ascribes to a contamination with a minute proportion of iron. The affinities, indeed, by which the decomposition is produced, he supposes to be those of iron for oxygen, of iron for potassium, and of potassium for hydrogen.

ALEMBIC, GLASS, fig. 58, plate I.—This is one of the numerous apparatus of distillatory vessels. In this country the use of the glass alembic is almost superseded by the retort and still. As distillation consists in reducing to vapour such substances as are susceptible of it, in a close apparatus, so contrived that the vapour received at a distance from the fire, in cooled vessels, is there condensed, in order to assume a liquid form, it is obviously essential to every distilling apparatus that it should be composed of at least two parts, namely, the boiler or vessel *a* in which the materials are heated; and secondly, the vessel communicating with the former, in which the condensation of the steam or vapour commences. Of all the vessels destined to this use the alembic is the simplest and most ancient. *a* is the matrass, cucurbit, or boiler, into which the materials to be distilled are introduced. *b* is the capital or head, in which the vapours are condensed; it fits closely on the top of the boiler *a*. The capital *b* has its external circumference or base depressed lower than its neck; so that the vapours which rise, and are condensed against its sides, by the contact of the surrounding air, run down into the circular channel formed by its depressed part, from whence they are conveyed by the beak, or nose *e*, affixed to the glass capital, into the receiver *d*.

The capital *b* is usually tubulated, that is to say, it has a small projecting neck *c*, at the top furnished with a ground stopper *f*, as shewn in the design. This contrivance is convenient for introducing from time to time a fresh supply of materials intended to be distilled, without deranging the apparatus. The capital or head *b* is sometimes made air tight to the matrass by grinding, but this method is expensive. It may readily be luted to the matrass *a*, by slips of wetted bladder, or lutes of

the usual kind. Fig. 59, plate I. is a *plain* (not tubulated) capital.

The throat or neck of the capital of the alembic should fit into the neck of the body *a* and not encompass it. If the neck fits into the throat, the condensed fluid lies on the luting of the joint and may become contaminated by it.

The alembic has this advantage over the common retort, that the residues of distillation may be easily cleared out of the body *a*, which is not the case with the retort. It is likewise capable when skilfully managed of distilling a much larger quantity of liquid in a given time than a retort of equal capacity. Besides this, the alembic may be used for causing the vapours of bodies to act upon substances in a more convenient manner than can be done by means of the retort and receiver; for example, to show the action of sulphur upon alcohol: to perform this experiment, put pounded sulphur into the alembic; see fig. 3, plate VII. suspend within it a bottle *a* containing alcohol; then put on the cover *b*, and adjust to the beak a small matrass. Lute well the joinings, and heat the apparatus. The sulphur will be sublimated, and the alcohol volatilized. In this state the two bodies meet; the alcohol dissolves the sulphur, and you will obtain a liquor, slightly coloured, which is sulphuretted alcohol.

The heat is applied to the glass alembic by means of a sandbath. The alembic is embedded in the sand previous to the application of heat. The inferior conducting power of the sand does not allow the heat to approach the vessel but in that gradual way which will ensure its safety from cracking. See *a a* fig. 6, plate VII. For experiments in the small way the lamp furnace will answer every purpose, provided the bottom of the alembic is of an uniform thickness. The sliding ring *b* of

the lamp furnace, supporting the alembic, admits of being placed at any given distance from the flame, and, in addition to this, the lamp *c* can be adjusted by its own rack, which elevates or depresses the cotton wick.

Glass alembics are usually made from one pint to two quarts capacity. The body is sometimes made of earthenware or metal, and the capital only of glass. A silver alembic with a glass capital is useful for the preparation of the pure alcalies.

ALEMBIC, METALLIC.—See STILL.

ALUDEL, fig. 13, plate II.—The aludels of the earlier chemists are a series of pear-shaped pots *a, a, a*, generally made of earthenware, but sometimes of glass, open at both ends. Each aludel has a short neck at top and bottom, so that a series of them may be fitted together by means of the neck in succession. Aludels were formerly used for the purpose of collecting the products of sublimations.

The joinings are made air tight by luting; sometimes the narrow extremity of the aludels entered into a round top containing the substance to be sublimed, whilst the upper aludel receives the sublimate. It was in an apparatus of this kind that those crystalline sublimes formerly called *flowers*, as flowers of sulphur, of Benzoe, &c. used to be prepared. This contrivance has been discarded, and its place supplied by apparatus of more simplicity and greater expedition, because the whole quantity of the sublimed product was found to be contained in the first aludel series. The head of an alembic will serve very well to receive and condense the sublimed products; two matrasses, put mouth to mouth, fig. 1, plate I. are also occasionally used as subliming vessels.

ANVIL, fig. 10, plate VIII.—A small table anvil *a* fixed in a heavy wooden block *b*. It is convenient for breaking the contents of crucibles, in order to separate the fluxes or glassy matter, from the metallic or other substances adhering to it; also for exploding fulminating compounds by the blow of a hammer, &c.

AREOMETER.—See **GRAVIMETER**, **HYDROMETER**.

AREOMETRICAL BEADS are a series of hollow glass balls, of the size of a large pea, increasing and diminishing in their specific gravity from a standard fluid (usually water) in a known ratio. When a fluid is to be tried, these balls, which are all numbered, are placed successively in the fluid, some of them will sink to the bottom of the vessel, and others remain on the surface of the fluid; whilst of course that bubble which is precisely of the same specific gravity with the fluid, will remain in any part of it, without shewing any tendency either to ascend or to descend. They are used for estimating the strength of spirituous liquors.

AREOMETRICAL BOTTLE. — See **SPECIFIC GRAVITY BOTTLE**.

ASSAY FURNACE, fig. 12, plate XV.—The construction of this furnace is simple and obvious. Its form is square, terminating in a truncated open pyramid; *c c c c*, doors with handles, with semicircular apertures for inspecting the operation; *a a a*, iron bands fixed with screws; *d*, the ash-pit. The fuel is put in at top. To the upper part of the furnace is affixed a perpendicular sheet iron tube, to serve as a chimney. It is used for assaying, and enamelling.

ATMOMETER, an instrument invented by Leslie, designed to measure the quantity of evaporation from any humid surface in a given time.

It consists of a thin ball of porous porcelain biscuit, two or three inches in diameter, with a small neck, See fig. 14, plate VIII. to which is firmly cemented a long and rather wide glass tube, bearing divisions, which correspond each to an internal annular section, equal to a film of water that would cover the outer surface of the ball to the thickness of $\frac{1}{1000}$ part of an inch. These divisions are numbered downwards to the extent of 100 or 200. To the top of the tube is fitted a brass cap, having a collar of leather, and which, after the cavity has been filled with distilled or boiled water, is screwed tight. The outside of the ball being now wiped dry, the instrument is suspended out of doors, and exposed to the free action of the air. The following statement with regard to this instrument is copied from Mr. Leslie work on heat and moisture.

Evaporation is always proportioned to the extent of the humid surface, for if a sheet of wet paper be applied to a plate of glass, it will, in a close room, lose its weight exactly at the same rate, whether it be held vertically or horizontally, and whether it occupies the upper or the under side of the plate. The quantity of evaporation from a wet ball is therefore the same as from an equal plane surface, or from a circle having twice the diameter of the sphere. In the atmometer, the humidity transudes through the porous substance, just as fast as it evaporates from the external surface; and this waste is measured, by the corresponding descent of the water in the stem. At the same time, the tightness of the collar, taking off the pressure of the column of liquid, prevents it from oosing so profusely

as to drop from the ball, an inconvenience which, in the case of very feeble evaporation, might otherwise take place. As the process goes on, a corresponding portion of air is likewise imbibed by the moisture on the outside, and being introduced into the ball, rises in a small stream, to occupy the space deserted by the subsiding of the water in the tube. The rate of evaporation is nowise affected by the quality of the porous ball, and continues exactly the same when the exhaling surface appears almost dry, as when it glistens with abundant moisture. The exterior watery film attracts moisture from the internal mass with a force inversely as its thickness, and will therefore accommodate the supply precisely to any given degree of expenditure. When this consumption is excessive, the water may be allowed to percolate, by unscrewing the cap, avoiding however the risk of letting it drop from the ball.

The atmometer is an instrument evidently of extensive application and of great utility in practice. To ascertain with accuracy and readiness the quantity of evaporation from any surface, in a given time, is an important acquisition, not only in meteorology, but in agriculture, and the various arts and manufactures. The rate of exhalation from the surface of the ground is scarcely of less consequence than the fall of rain, and a knowledge of it might often direct the farmer advantageously in his operations. On the rapid dispersion of moisture, depends the efficacy of drying houses, which are too frequently constructed most unskilfully, or on very mistaken principles. But the purposes to which this atmometer so aptly applies were hitherto supplied in a rude and imperfect manner. The loss that water sustains in a given time from evaporation has commonly been estimated by weight or measure. If a piece of

flannel, stretched by a slender frame, be wetted and suspended in the free air, its dissipation of moisture, after a certain interval, is found by help of accurate scales; or if water in a shallow pan be exposed in a similar situation, its daily waste is detected by the application of a finely divided rod or gage. But these methods are extremely troublesome, and are subject, besides, especially the latter one, to great inaccuracy. Both the flannel and the sheet of water require to be sheltered against the wind and rain, and consequently they will not exhibit, like the atmometer, the real exhalation which takes place from the ground. The bottom and sides of the pan must also, from their extent of dry surface, affect the temperature of the water, and consequently modify the quantity of evaporation.

An atmometer, suspended in still air, might therefore, on taking into account the time intervened, answer nearly the purpose of the hygrometer; and this mode can be employed with advantage, in discovering the mean dryness of an apartment after the lapse of hours or days. Its delicacy indicates directly, and almost spontaneously, the actual dryness of the medium. This instrument is hence indispensable in all meteorological observations, and may contribute essentially towards laying the foundation of a juster and more comprehensive knowledge of the various modifications which take place in the lower regions of our atmosphere. Heat and moisture are the chief agents which nature employs in producing those incessant changes; and if the invention of the thermometer has tended so much to correct and enlarge the views of physical science, may not the introduction of an accurate hygrometer be expected to confer a similar benefit, and to direct our researches into many departments that are still unexplored.

In the regulating of many processes of art, and in directing the purchase and selection of various articles of produce, the application of this instrument would render material service. Most warehouses, for instance, require to be kept at a certain point of dryness, and which is higher or lower according to the purposes for which they are designed. The printing of linen and cotton is carried on in very dry rooms, but the operations of spinning and weaving succeed best in air which rather inclines to dampness. The manufacturer is at present entirely guided by observing the effects produced, and hence the goods are often shrivelled, or otherwise injured, before he can discover any alteration in the state of the medium. But were an hygrometer, even of the most ordinary construction, placed in the room, it would exhibit every successive change in the condition of the air, and immediately suggest the proper correction. The same means could be employed most beneficially, in attempering the atmosphere of public hospitals.

That wool and corn have their weight considerably augmented by the presence of moisture is a fact well known. Without supposing that any fraudulent practices are used, this difference, owing merely to the variable state of the air, in which the substances are kept, may yet in extreme cases amount to ten or even fifteen *per cent.* Grain or paper preserved in a damp place will be found to swell nearly after the same proportion. But the real condition of such commodities might easily be detected, by placing the hygrometer within a small wired cage, and heaping over this, for a few minutes, a quantity of the wool or grain which is to be examined.

BALLANCE, fig. 5, plate II.—The ballance, or pair of scales, is an instrument sufficiently known. It serves to ascertain the equality of the absolute or difference of weight of bodies. The absolute weight of bodies is relative, it being the expression of a number denoting its relation to some arbitrary or conventional standard, as a pound, an ounce, a drachm, of which it is a multiple or aliquot part. The best kind of *hand scales* are those which are furnished with a box end *a*, and have a ring or sight hole at the upper extremity of the fork which supports the beam. The chemist should be provided with scales of different sorts and delicacy, for the beginning and end of every exact chemical process consists in weighing. With imperfect instruments this operation will be tedious and inaccurate; but, with a good ballance, the results will be satisfactory; and much time, which is so precious in experimental researches, will be saved. It is requisite to have scales for ordinary use, and others for occasions where greater delicacy is necessary. Fine scales should always be kept apart from the laboratory, in some place where the vapours of acids, or other corrosive liquors, cannot have access to them, otherwise they rust, and the accuracy of the ballance is destroyed; for the same reason they never should be overloaded. The beam of a good balance should remain in equilibrio without the scales, and when the scales are changed, and should be very sensibly affected with a small portion of additional weight when loaded. They should hang in a dry place, and in a good light. The most delicate scales should be kept in glass cases, and should not be taken out without occasion.

BALLANCE HYDROSTATIC.—A kind of ballance contrived for finding the specific gravities of bodies, both solids and liquids. The workmanship of this instrument requires peculiar nicety, but an accurate and delicate pair of scales of the usual construction when supported on a stand, may be made to answer the purpose, see fig. 2, plate VII. It only requires to shorten the strings of one of the pans *a*, as shewn in the figure, and to affix underneath and in the centre of the shortest pan *a*, a small hook *b*. This ballance when in use might be held in the operator's hand, but as the experiments to be performed with it requires usually much time and accuracy it is advisable to have the ballance adapted to a stand. As the hydrostatic ballance is used for finding the *comparative* weight of equal bulks of bodies, a standard of comparison must be assumed, and distilled water has been generally taken as unity. The specific gravity of any solid is ascertained by comparing the weight of the body in the air with its weight when suspended in water. The quotient obtained by dividing its weight in air, by the difference between its weight in air and its weight in water, is its specific gravity. The specific gravity of fluids may be ascertained by comparing the weight of a solid body, such as a piece of crystal *c*, when immersed in distilled water, with its weight when immersed in the fluid we wish to examine; by dividing its loss of weight in the fluid by its loss of weight in the water, the quotient is the specific gravity of the fluid.

BALLOON.—This name is given to a large globular glass receiver, with a short neck, fig. 15, plate IX. Fig. 14, plate IX. is a tubulated balloon receiver.

BAROMETER, fig. 11, plate XIV.—The tubes of which barometers are made ought at least to be $\frac{1}{4}$ of an inch bore; or about $\frac{1}{3}$ of an inch is better. The tube should be new, and perfectly clean within. In order to be certain of this, it should be hermetically sealed at both ends, at the glass-house, when made; one of the ends may afterwards be cut off with a file. The mercury ought to be perfectly pure.

To fill the tube with mercury, warm it, and pour some mercury into it by a small paper funnel, so as to reach within an inch of the top; you will see that as the tube fills there are bubbles of air in several parts. When the tube is full, apply your finger against the open end, and invert the tube, by which means the air that was on the top, now rising through all the quicksilver, gathers every bubble in its way. Turn the tube up again, and the bubble of air re-ascends; and, if there are any small bubbles left, carries them away. If, however, any remain, the operation must be repeated. The tube is now to be filled to the top, and stopping the open end with the finger, must be inverted into a basin filled with mercury, after which the finger may be withdrawn under the surface of the mercury; the mercury in the tube will subside, remaining suspended at the height of 29 or 30 inches, or whatever balances the pressure of the atmosphere at the time. The space at the top of the tube is a perfect vacuum.

The following is a still better way of filling the tube: pour the purest mercury into the tube (which must be very dry and well cleaned), to within two inches of the top, and then hold it with the sealed end lowest, in an inclined position, over a chafing-dish of burning charcoal, placed near the edge of a table, in order that all parts of the tube may be exposed successively to the

action of the fire, by moving it obliquely over the chafing-dish. The sealed end is to be first gradually presented to the fire. As soon as the mercury becomes hot, the internal surface of the tube will be studded with an infinite number of air-bubbles, giving the mercury a kind of grey colour; these increase in size, by running into one another, and ascend towards the higher parts of the tube, where, meeting with a cooler part of the fluid, they are condensed, and nearly disappear. In consequence, however, of successive emigrations towards the upper parts of the tube, which are successively heated, they finally acquire a bulk which enables them in their united form entirely to escape. When the first part of the tube is sufficiently boiled, move it onward, by little and little, through its whole length. When the mercury boils, its parts strike against each other, and against the sides of the tube, with such violence, that a person unacquainted with the operation, naturally apprehends the destruction of his tube. By this process, the mercury is entirely deprived of the air which adhered to it.

The tube is now fixed with its basin to a wooden frame prepared for it, as shewn in the design, fig. 11, plate XIV. having a scale of inches at the upper end, which is accurately measured from the surface of the mercury in the cistern. Fig. 8, plate XIV. shews the scale at the top, drawn larger.

This is the common construction of the barometer, and is still found to be the best of any.

BAROMETER, WHEEL BAROMETER, fig. 12, plate XIV.—*a* represents the quicksilver in a glass tube, having a large round head or ball, and turned up at bottom *b*; upon the surface of the mercury in the re-

curved leg, there is then placed a short glass tube loaded with mercury, with a string going over a pulley, and is balanced by another weight hanging freely in the air. As the surface at *a* is very large, and that at *b* very small, the motion of the quicksilver, and consequently of the ball *a*, will at bottom be very considerable; but as the weight moves up and down, it turns the pulley, and that a hand or index; and by the divisions of a large graduated circle, the minutest variations of the air are plainly shewn, if the instrument be accurately made, and the friction of the several parts be inconsiderable.

BASIN.—See **EVAPORATING BASIN.**

BATH, SAND BATH.—The heat communicated from bodies in combustion must necessarily vary according to circumstances; and this variation not only influences the results of operations, but in many instances endangers the vessels, especially if they be made of glass. Among the several methods of obviating this inconvenience, one of the most usual consists in interposing a quantity of sand, or other matter, between the fire and the vessel intended to be heated.

Of all kinds of chemical baths that which is used the most extensively is the *sand bath*. In experimental furnaces, or smaller chemical operations, the vessel to contain the sand is a cast iron pot, very much in the form of an inverted round hat, fig. 7, plate X. of which the hollow part is supported by the projecting rim upon the sides of the furnace, and hangs down over the burning fuel, the flame of which plays round it and gradually heats the sand which it contains, together with every vessel buried therein. See *a* fig. 6, plate XV.; *a* fig. 15, plate XV.; fig. 23, plate XV.; *x* fig. 7, plate VII. and fig. 12, plate XIII.

In this bath the heat is gradually communicated, although less uniformly than by the water bath; and it may likewise be carried to ignition. As the heat is greatest towards the bottom of the sand, the operator possesses a power of moderating it by raising the vessels when necessary. The extensive sand bath which is formed by spreading sand upon an iron hearth, fig. 10 and 11, plate XV. is very useful for digestion, solution, evaporation, and other chemical processes, which may be carried on, at the same time, in a considerable number of vessels.

This sand-bath is generally constructed of masonry. At the front is a rim, made of free-stone or sheet iron, about four inches deep, fastened, or let in, at each end into the wall. The bed *ee* is formed of cast-iron plates which rest upon each other in corresponding rabbets. The advantage of several plates over one large one is the cheapness and facility with which they are replaced if cracked by the heat, an accident of not unfrequent occurrence. The joints of the plates are secured by loam or clay, which effectually prevents the sand from falling through. The fire-place is shewn by *b*; *a* is the ashpit. The flame and smoke circulate first through the flue *c*, and then through the returning flue *d*, which conveys the smoke to the chimney. In constructing the flue beneath the grate, a row of bricks set edge-ways answers the purpose, and serves also to support the inner edge of the plates.

The sand should be of middling fineness, the finest as well as the very coarsest being separated by sifting; for by this means the heat is more gradually distributed. Those distillations, which at any part of the process require as much as a low red heat, are usually performed in sand baths, even in manufactures in the great way.

Sand, when thoroughly heated, continues hot for a very considerable length of time.

BATH, STEAM BATH.—Is a contrivance so called in which a vessel to be heated is exposed to the action of steam. Fig. 4 and fig. 7, plate XIII. exhibits a steam bath, constructed for the lamp-furnace, it is particularly serviceable for drying such materials as cannot be exposed to a temperature exceeding that of boiling water, such as fulminating mercury, &c. Fig. 6, exhibits a section of this steam bath.

Such fulminating compounds as are to be dried must be placed in the conical glass vessel *b*, and when the vessel *e* is filled with water up to the side tube *d*, the desiccation may be performed without any risk of explosion, or any further trouble, by putting the apparatus over a lamp, and keeping the water in a state of ebullition. It is particularly useful in the drying of the precipitates obtained in the analysis of minerals. It is well known that the same mineral analysed by different chemists, has been found to yield different proportions of the same ingredients, and that the difference of proportions of the constituent parts, in many cases, is often more apparent than real; arising entirely from the various degrees of desiccation that have been employed by different analysts, and sometimes even by the same person. This point is of such importance, that every chemist will at once perceive the utility of the apparatus in this respect.

The apparatus may likewise be used as a water-bath. In that case, the conical glass vessel *b* is removed, and the inner copper vessel *e* filled with water; into this, small retorts, flasks, vials, &c. may be immersed for promoting the processes of distillation, digestion, solution, evaporation, &c.; or it may be used as a sand-bath (it being

hard soldered) by filling the copper vessel with sifted sand, for performing those operations which require a higher temperature than that of boiling water.

BATH, WATER BATH.—The water bath is nothing more than a pan, fig. 10 and fig. 11, plate XVI. fig. 64, plate I. containing water kept boiling, and in which the digesting or distillatory vessels are kept immersed. The heat of boiling water is nearly stationary, this temperature is found very advantageous in the distillation of essential oils, and all other substances in which an empyreumatic taint is to be feared. It may easily be imagined, that the form of the bath, as well as of the vessels, may be varied according to the purposes respectively aimed at; any vessel, full of water, capable of being heated to boiling, may be used as a water bath. As the utmost heat which any substance immersed in a boiling liquid can acquire thereby, falls short by a few degrees of the temperature of the liquid itself, the heat of a water bath cannot amount to 212° . This is considerably increased, however, by using a strong solution of sea-salt, or any other salt, instead of water; as the boiling point of saturated brine is much higher than that of mere water. This forms the ancient *Balneum Maria*, *Bath of Mary* (the *Virgin*, as some have interpreted the term); but others with more plausibility write *Balneum Maris*, *seawater*, or *brine-bath*.

BEADS, SPECIFIC GRAVITY.—See **AREOMETRICAL BEADS**, page 40.

BELL GLASS.—See **AIR JAR**, figs. 23, 24, plate IV. page 32.

BELL GLASS, DEFLAGERATING BELL GLASS.—See **AIR JAR**, page 32.

BELL GLASS, WITH STOP-COCK, fig. 50, plate I.
—Bell glasses of this kind are convenient for transferring gases into exhausted vessels, or into bladders, &c.

BELL GLASS AND BLADDER APPARATUS, fig. 47, plate I.—This is one of the most useful apparatus in the whole collection of chemical instruments for operating on gases, on account of the vast number of purposes to which it may be applied. It consists of a bell-glass *a*, furnished with a brass cap and stop-cock *b*. *c* is a small connecting piece, with two female screws, by means of which a second stop-cock *d*, affixed to a bladder *e*, or to any other vessel, may be connected with the stop-cock *b*, and the receiver *a*. If the bladder *e*, has been previously compressed, and a communication be then made with the bell-glass *a*, by opening both stop-cocks, the gas contained in the bell-glass may of course be transferred into the bladder, by pressing down the bell-glass *a*, into the water of the pneumatic trough, the gas will be forced up into the bladder; the stop-cock being then shut, the bladder may be removed.

BELL RECEIVER.—See **AIR JAR**, figs. 21, 23, 24, plate IV. page 32.

BLADDER, WITH STOP-COCK, fig. 15, plate XI.—A large bladder mounted with a stop-cock is very convenient for throwing up soap bubbles filled with hydrogen, or a mixture of oxygen and hydrogen gas, and for other occasional purposes on gases. The bladder is firmly tied to a stop-cock *a*, which fits the stop-cock of the air holder, fig. 16, plate XI. or any air jar containing the gas, and furnished with a brass cap and stop-cocks

fig. 5, plate I. For throwing up soap bubbles inflated with hydrogen, a small brass tobacco pipe, fig. 45, plate I. is fitted to the stop-cock of the bladder, and by means of the flexible jet pipe, fig. 46, plate I. the gas may be transferred from the bladder as occasion may require.

BLAST FURNACE, (AIKIN'S), fig. 9, plate X.—To excite a sudden heat, and to raise it rapidly to the greatest intensity, nothing can be better calculated than this simple furnace. By the ingenious contrivance of dividing a strong blast of air, issuing from a double bellows, and driving it forcibly, first into a small chamber *a*, and from thence perpendicularly into a number of converging jets, through the centre of the fire place, a most intense heat is rapidly produced, sufficient to melt down cast iron, if the fire be properly managed, and the bellows *c* worked with vigour. Coke or cinders, free from clinkers and dust, taken from the common grate, when the coal just ceases to blaze, broken into fragments of the size of a walnut, and mixed with a little charcoal, form an excellent fuel for this furnace; the fire being first kindled by a few lighted cinders and a small quantity of charcoal or chips of wood. This furnace is composed of three parts, all made of black lead. The lower part, *a*, fig. 9, contains the blast chamber; to this is fitted the body of the furnace *b*, which is perforated with blast holes at the bottom; 10, is the upper part or dome inverted upon *b*; it serves to concentrate the heat with more efficacy, and to make it reverberate on the bodies exposed to it in *b*; it also protects the eye from the intolerable glare of the fire when the furnace is in full heat; 14, is a pair of double bellows fixed on the stool; *g*, the handle, is lengthened to make them work easier. If a very strong blast be wanted, a heavy weight may be secured to the upper board of the bellows.

BLAST FURNACE, (LEWIS'S), fig. 12, plate X.—This furnace consists of two black lead pots, *a*, *b*, placed one within another. The inner or smaller one *a*, as shewn in the section, fits the outer one *b*, accurately at the brim, where it is secured by lute. It is perforated all round, to admit a blast from the bellows, the nozzle of which is introduced into the hole *c*. *d* shews a crucible placed on its stand in the furnace. This furnace may be used with coke and charcoal for common purposes.

BLOWPIPE, (BERGMAN'S) fig. 17, plate I.—The blow-pipe in chemistry and mineralogy is an instrument of the greatest utility. It enables us to expose to the action of a most violent heat, in a ready way, any substance we may meet with, in order to ascertain its general nature or qualities with regard to fire: all the effects of the most intense heat of furnaces may instantly be produced by this instrument; and with this advantage that the process is expeditious, and under the inspection of the operator; whereas we can only conjecture what passes in the centre of a furnace, if the same experiment be made on a large scale. The most expensive materials, and the minutest quantity of bodies, may be used, and the whole process instead of being carried on in an opaque vessel, may instantly be varied under the eye of the observer, and may be seen from beginning to end. Indeed many advantages may thus be derived from the use of this simple and valuable instrument. Its smallness, which renders it suitable to the pocket, is no inconsiderable recommendation to the travelling mineralogist. It is true that very little can be determined in these minature assays, concerning the proportional quantity of products, but in most cases a knowledge of

the contents of any mineral substance is a great acquisition, which is thus obtained, in a very short time, although the actual quantities are too minute to enable the operator to ascertain their relative proportions.

It requires a little art to keep up an uninterrupted blast of the blow-pipe with the mouth, which is not easily described; but may readily be acquired by practice. The act of breathing must be carried on through the nostrils without interruption, and the stress of blowing must be performed merely by the compression of the cheeks upon the air in the mouth. Beginners blow generally too strong, which obliges them to take breath very often. The whole art consists in inspiring the air through the nostrils, whilst the air contained in the mouth is forced out through the blow-pipe, so that the action of the nostrils, lungs, and mouth, resemble the action of double bellows; and to accomplish this object, there is no necessity of blowing violently, but only with a moderate and equable force, and then the breath can never fail the operator. This art of blowing properly is by some acquired in an instant, while others are a long time in making themselves masters of it. To those who experience any difficulty in the free use of the blow-pipe, the following directions may be of service. First, let the learner accustom himself to breathe freely with the mouth shut; then in making an expiration, let him transfer the air into the mouth, till the cheeks are moderately inflated, and retaining it there, let him discharge the surplus of the expiration through the nostrils, without allowing the air in the mouth to escape. When practice has rendered this easy, which may be effected in half an hour, let the nozzle with the smallest aperture be fixed on the jet tube of the blow-pipe, and introduce the mouth piece within the lips; then inflate the cheeks

by an expiration, and continue breathing easily through the nostrils, till nearly the whole of the air has passed out of the mouth through the tube; then renew the air as before, and after a few day's practice, the muscles of the mouth will be accustomed to this new mode of exertion, and an uniform uninterrupted stream of air may be kept up for half an hour without any extraordinary fatigue.

The best kind of flame for blowing through with the blow-pipe is a thick wax or tallow candle with a very large wick, which should be kept snuffed moderately low, and the wick turned a little aside from the pipe; the spirit lamp may also be used, it makes a perfectly clear flame without smoke, but weak in comparison to a thick wax candle; although a wax candle is the most convenient, a thick tallow candle will do very well. The candle should be snuffed rather short, and the wick turned on one side towards the object, so that a part of it does lie horizontal. The stream of air must be blown along this horizontal part as near as may be without striking the wick. If the flame be ragged and irregular, it is a proof that the hole of the blow-pipe nozzle is not round or smooth; and if the flame have a cavity through it, the aperture of the nozzle pipe is too large. When the hole is of a proper figure, and duly proportioned, the flame consists of a neat luminous blue dart or cone, surrounded by another flame of a more faint and indistinct appearance. Too great a flame does not easily yield to the blast, and too small a one, produces a weak effect.

In using the blow-pipe, the following observations should be attended to. The end of the nozzle pipe *a* must be just entered into the flame, and the current of air will then throw out a cone or dart of flame from the

opposite side. If it is well managed, this dart or cone will be very distinct and well defined. Care must be taken that the stream of air does not strike against any part of the wick, as it would then be disturbed, and split into several parts. The jet or blast of air must be delivered somewhat above the wick; and as, unless the flame was considerable, there will not be sufficient for the stream of air to act upon, for this reason the wick is best to be opened, because it then exposes the largest surface, and produces the greatest flame; the stream of air from the pipe should then be directed through the channel or opening between the wick, so as to produce a cone the most perfect and brilliant, directed downwards, at an angle of about 45 degrees.

Its intensity is different according to the different parts of the flame. The place where this intensity is strongest, is the extremity of the blue point of the flame.

Every substance intended to be assayed with the blow-pipe, should be heated very gradually, the flame should be directed very slowly towards it, in the beginning, not directly upon it, but somewhat above it, and so approaching nearer and nearer with the flame, until it becomes red hot. Whenever any mineral substance is to be tried, we do not immediately begin with the blow-pipe, because minerals are not always homogeneous, or of the same kind throughout, although they may appear to the eye to be so. A *magnifier*, fig. 7, plate V. is therefore necessary to enable us to discover the heterogeneous particles, if there be any, and these ought to be separated, and every part tried by itself, that the effects of two different things examined together, may not be attributed to one alone.

The substance upon which the flame acts ought to be proportioned to the size of the flame to which it is

exposed. If the aperture of the blow-pipe is only of the diameter of a common pin, the substance ought not to be larger than a pepper-corn. In order to support the substance, it may be laid upon a piece of close-grained well-burned charcoal, made of elm or poplar wood. A small shallow hole may be scooped out with a knife, on the piece of charcoal, and the substance laid upon it. The charcoal itself kindles all round the hole, and the hole is thus gradually enlarged; and the heat too is kept up round the substance much more uniformly than when a metal support is used. At the same time, however, the chemical effect produced by ignited charcoal should not be forgotten, particularly in the reduction of metallic oxides, and the deoxygenation of the fixed acids; so that, for example, a small heap of oxide of copper, lead, or tin, heated red-hot on charcoal by the blow-pipe, is speedily reduced to a metallic state, hence also fragments of tin stone (tin ore), common lead ore, or galena, ruby copper, &c. are easily reduced when heated on a charcoal support.

Very small and brittle substances are apt to be carried away by the current of flame from the piece of charcoal. These may be secured by making a deep cavity in the charcoal, into which the substance is to be put, and covered with another small piece of charcoal, which partly protects it from the flame. Some experiments of reductions are best made by binding two flat pieces of charcoal together, cutting a channel along the piece intended to be uppermost, and making a cavity in the middle of this channel to contain the matter to be examined. With this contrivance the flame may be urged through the channel between the two pieces of charcoal, and thus violently heats the substance in the cavity, which may be considered as in a closed furnace.

BLOW-PIPE, (Dr. BLACK'S.)—A conical tube with a jet pipe *a*, at its base, as represented fig. 17, plate I.

BLOW-PIPE, (BROOKE'S) OXY-HYDROGEN BLOW-PIPE, figs. 5 and 6, plate III.—The instrument known by this name is a box of sheet copper *a*, to which a condensing syringe, a jet *c*, and a contrivance to ensure safety from explosions, are attached. The principle on which it acts is the elasticity of the air; air being thrown into the reservoir by means of the syringe, is there retained in a condensed state, until the jet-cock is opened, when its elasticity causing it to issue with great force from the orifice, a stream is formed; which may be thrown, by means of a universal joint *d*, in any direction on the flame of a lamp.

As the nature of the instrument permits the introduction of any gas or mixture of gases into it, it has given rise to a frequent and effectual application in the production of intense heat, by the combustion of a stream of oxygen and hydrogen gases from the jet; but as these mixtures when confined in any quantity, cause on inflammation, violent and dangerous explosions, it was necessary that some farther addition should be made to the apparatus than what was required to fit it for the use of a single gas, to prevent the inflammation passing from the jet *c* backwards to the mixture in the reservoir *a*.

On the principle of safety laid down and demonstrated by Sir Humphrey Davy, small tubes of glass were used in the first instance with perfect success; but as a slight variation in the diameter of the bores rendered them incapable in certain circumstances of preventing the passage of the flame backwards, a small apparatus has been attached to the instrument, to render it perfectly secure.

This additional part is called the trough; it is inserted in the box, the upper part, or head *e*, only appearing above; from this head proceeds a stop-cock, *f*, to which the jet is fixed.

When the head *e* is taken off, by means of the key *k*, the interior of the trough is seen. It consists of a circular vessel, descending to the bottom of the reservoir, and intersected at about two-thirds of its depth by a piece of very fine wire gauze. At the bottom of the vessel is a valve which covers four small holes connected with a small tube, rising by the side of the trough to the upper part of the reservoir, but concealed in its interior. The top of this tube is covered with fine wire gauze to prevent foreign matter getting from the reservoir to the valve, and there is a third screen, of the same kind, within the head of the trough.

When the instrument is to be used it should be put together, with the upper end of the syringe connected with the stop-cocks, at the hinder part of the reservoir, as in fig. 6, and then on working the piston, the syringe exhausts the reservoir of the air it contains; the stop-cocks should then be closed, and the syringe taken off and placed in its upright position, as in fig. 5, and then the bladder *g*, containing the mixture of gases, being connected with the part before attached to the reservoir, the gas will issue from it on the stop-cocks being opened, and fill the vacuum formed by the previous process.

This being done, the head of the trough is to be unscrewed, and water poured in to about half an inch above the lower screen of wire gauze, and then the head is to be put on very tightly as before. The mixed gases are now to be condensed into the reservoir, by working the piston until the contents of one or more bladders, as may be deemed requisite, are thrown in, and then all

the stop-cocks being shut, the instrument is ready for action.

The jet *c* should be gradually opened before the light is applied to it, and the ear being brought near the box, endeavours should be made to hear the play of the water in the trough as the gas passes through it; if that is evident, all is right, and the current may be inflamed at the jet pipe; if no sound is heard of the water bubbling, then, whether a stream issues or not from the jet, something is wrong, and the head of the trough should be taken off to ascertain the state of things within. This, however, may almost be called a useless precaution, since an occurrence of the kind has never happened, and does not appear possible, if the apparatus be in order. Should it happen, it must be occasioned by the passage of the water backwards into the reservoir, owing to an inefficient valve, and the apparatus should not be used, but sent to be repaired by the workman who constructed it.

During the whole time the flame is burning, the water will be heard to play in the trough. If the current is inflamed, and the instrument abandoned to itself, the flame will go on burning, until the expansive force of the atmosphere, within the box, is no longer sufficient to propel a stream with the required rapidity through the tube; at this time the inflammation will pass backwards, unless the tube is very fine, and will fire the small quantity of mixture in the upper part of the trough, and then its effects will cease, the atmosphere in the reservoir remaining as before. When, however, the regular use of the instrument is required, it is better to shut the jet-cock *f* before the atmosphere is quite out, and condense in a fresh portion of gas.

Attention should be paid to the quantity of water in

the trough—it should cover the wire gauze, but not to too great a height; if there be too much water it is possible that the agitation caused by the passage of the gas through it, may throw a drop or two through the gauze above against the inner orifice of the jet tube, which would cause a sputtering in the flame.

When a large jet or several small collateral jets are used a stronger current of gas is required to supply the combustion and keep it on the exterior of the orifice; the hand therefore should be retained on the jet-cock, opening it wider as the elasticity of the air within diminishes; if this is not done, the inflammation will pass through whilst the current still exists, and cause a combustion in the trough. Then two events may happen, neither of which, however, is in the least dangerous; the whole of the gas above the water may be fired, in which case the combustion is at an end; or, it may burn continuously on the upper surface of the wire gauze in the head of the trough, as long as any gas passes from the reservoir through the water. In the latter case the heat will be great on the wire gauze, and perhaps sufficient to injure it.

For this reason, as well as to provide against casualties, the apparatus should be examined each time before being used, that all may be in order; and when done with, and to be put aside for more than a few days, it is advisable to throw out the water from the trough.

As a superabundance of caution is certainly better than that which we may conceive to be sufficient, it will be as well to notice, that the end of the reservoir nearest to the syringe is always made weaker than any other part; so that if an explosion happens purposely, or by some unforeseen accident, it will find vent at that

place in preference to any other, and in a few instances that have happened in the first trials with this instrument, either for experimental illustration or otherwise, that part and no other has always yielded; the simple precaution, therefore, of standing away from the end, when an instrument from long wear or other causes acts badly, may be attended to.

BLOWPIPE, (DR. WOLLASTON'S), figs. 22 and 23, plate I.—It consists of three tubes, so adapted to each other that they may either be packed together, or one within the other, the whole is reduced to one half of its real dimensions in the sketches.

In fig. 22. the interior tube is shewn to be somewhat longer than the exterior; and it is made so, that it may be more readily withdrawn.

In each figure, the upper edge of the large end appears turned outward, in order to diminish the effort of the lips requisite for retaining it in the mouth.

In fig. 23, it will be seen that the small extremity is placed obliquely, at an angle of about 120 degrees, that the flame impelled by it may be carried to a more convenient distance from the eye, so as to answer the purpose of a longer blow-pipe.

The oblique piece *a* is itself composed of three parts, of which the largest is made stronger than the rest of the blow pipe, that it may not be strained by frequent use. One end of this is closed, and into the other is inserted a small peg of wood, perforated so as to receive the tip, which is intended to be occasionally separated, for the purpose of passing a fine needle into it to remove any accidental obstruction.

BLOW-PIPE, SELF-ACTING, fig. 6, plate II.—The action of this blow-pipe depends on a rapid stream of alcoholic vapour passing through the flame of a lamp, attached to the instrument. It produces a cone of blue fire, five or six inches long, accompanied with a hissing noise. The whole apparatus is neatly turned in brass. A globe of copper *a*, which contains spirit of wine, rests on the frame *g*: the tube *x* is continued within the globe almost to the top, and serves for conveying the spirit in the form of vapour, or gas, to the flame *o* of the lamp *p*. *f* is a safety-valve, occasionally forced up by the vapour, which would otherwise burst the apparatus. *y* is the opening by means of which the spirit is introduced.

The flame of the lamp boils the spirit of wine, which comes over through the tube *x*, in the form of gas, and being conveyed through the wick of the lamp, produce a heat strong enough to melt glass, &c.

BLOW-PIPE, WITH SELF-ADJUSTING CANDLESTICK, fig. 3, plate III.—*a* is the candlestick, which may be slid backwards and forwards upon the plate. The rack in the tube serves to raise the candle. The ball *b* of the blow-pipe, together with its jet tube *e, e*, which may also be raised and lowered in order to direct the point accurately towards the flame. The charcoal stand is likewise moveable upon the base *f*; but at the same time, as the drawing shews, its pillars are by means of the sliding pieces, capable of a lateral motion besides that the charcoal can be vertically turned upon the pillar. It is an expensive apparatus.

BLOW-PIPE, WITH STOP-COCK, fig. 46, plate I.—*a* is a metal blow-pipe, screwed into the stop-cock *b*,

which may be joined to a bladder. The bladder being filled with oxygen gas, a very intense heat may be produced by directing the stream of gas on a piece of ignited charcoal.

BLOW-PIPE APPARATUS.—A small mineralogical case for the pocket, containing a blow-pipe, a double magnifier, platina foil, a blow-pipe forceps, bottles of fluxes, a steel graver, test tubes, and the most essential re-agents necessary for the immediate examination of minerals. It affords a convenient way for examining the nature or composition of minerals, though the actual quantities of the substances discovered are too minute to enable the operator to ascertain their relative proportions.

BLOW-PIPE SPOON, fig. 13, plate X.—Those bodies upon which charcoal acts chemically when intended to be exposed to the blow-pipe flame, without suffering such changes to take place, may be placed in a small spoon, somewhat less than a quarter of an inch in diameter, made of gold, silver, or platina. The spoon must be properly fixed into a wooden handle *a*. Silver or gold spoons are best adapted for fusions with alkaline fluxes, for which those made of platina are entirely unfit; they have nevertheless the capital disadvantage that they will only bear a dull red heat without risk of melting, whereas spoons of platina are perfectly infusible by the blow-pipe flame.

BLOW-PIPE FORCEPS, fig. 4, plate V.—This small forceps, which is entirely made of platina, is convenient and useful for easily exposing solid materials to the dart of the blow-pipe flame. They cannot be

melted nor oxidated, nor do they become too hot to be held by the fingers during trial, on account of the bad conducting power of the metal of which they are fabricated. They are also convenient for handling or taking out from melted fluxes the small bead of the product.

BLOW-PIPE FOIL.—This name is given to platinum foil, of the thickness of fine writing paper. It is very serviceable for exposing to the flame of the blow-pipe such substances as readily split, and are dispersed when heated by the blow-pipe dart on charcoal, or when held by the forceps in the spoon. Any substance, wrapped up in a piece of this foil, may readily be kept steady during trial.

BOILER, fig. 6, plate VI.—This figure exhibits the method of fixing large boilers, which of late has been adopted, and said to economise fuel. The boiler is set in brick work, and the furnace by which it is heated resembles a vault; and to add to the effect produced by the heat, the middle of the fire-place is rather larger than its sides, which makes it perceptibly concave, an opening is made also in the middle of the vault, which is intended to increase the rapidity and the strength of the fire.

BOILER, **STEAM BOILER**, fig. 16, plate IV.—The use of steam, which has been introduced as a vehicle and source of heat, affords an example of the scientific application of the principles of latent or combined caloric. By conveying steam into water, it is condensed, and by the evolution of the latent caloric by the condensation, the temperature of the water is raised, so as soon to arrive at 212°. In certain arts, as in that of

dyeing, where large quantities of water are to be heated in separate vessels, this method has superior advantages. By having a common boiler, from which the vapour is conveyed by tubes, the loss of heat is much less than if fire was applied to each vessel, and at the same time the vessels are subject to less wear, and may be constructed at less expence. This method has accordingly been employed with success.

This apparatus, which is copied from Henry's Chemistry, is useful for exhibiting the most important experiments respecting latent heat; *a* is an oval copper, copper boiler, &c. On the cock *c* may be screwed occasionally, a valve, loaded in the proportion of 14 pounds to the square inch. The boiler being rather more than half filled with water, and the perforated cap *d* being screwed into its place, the ball of the thermometer will be an inch or more above the surface of the water, and will indicate its temperature, as well as that of the steam, both being, necessarily, in all cases, precisely the same. Allowing the steam to escape through the cock *c*, before affixing the valve, the temperature of the steam, under a mean atmospheric pressure, will be 212° . When an additional atmosphere is added by the weighted valve, it will rise to above 240° ; by a valve twice as heavy as the first, or loaded in the proportion of 28 pounds to the square inch, the temperature of the steam will be raised to nearly 270° .

For elucidating the production of heat, during the condensation of vapour, &c. the right angled pipe *c* must be screwed air tight, into its place, and must be made to terminate at the bottom of a jar *f*, containing a known quantity of water of a given temperature. This conducting pipe and the jar should be wrapped round with a few folds of flannel. The apparatus being thus

disposed, let the water in the boiler be heated by an Argand's lamp, with a large wick, till steam issues in considerable quantity through the cock *c*, which is then to be closed. The steam will now pass through the right angled pipe *c* into the water contained in the jar *f*, which will condense the steam, and will have its temperature very considerably raised. Ascertain the augmentation of temperature and weight; and the result will show, how much a given weight of water has had its temperature raised by a certain weight of condensed steam. To another quantity of water, equal in weight and temperature to that contained in the jar at the outset of the experiment, add a quantity of water at 212° , equal in weight to the condensed steam; it will be found, on comparison of the two resulting temperatures, that a given weight of steam has produced, by its condensation, a much greater elevation of temperature, than the same quantity of boiling water. This will be better understood by the following example, taken from actual experiment:

Into eight ounces of water, at 50° Fahrenheit, contained in the glass jar *f*, fig. 16, steam was passed from the boiler, till the temperature of the water in the jar rose to 173° . On weighing the water, it was found to have gained $8\frac{1}{2}$ drachms; that is, precisely $8\frac{1}{2}$ drachms of steam had been condensed, and had imparted its heat to the water.

The large quantity of caloric latent in steam renders its application extremely useful for practical purposes. Thus, water may be heated, as in the foregoing experiment, at a considerable distance from the source of heat, by lengthening the conducting pipe *c*. This furnishes us with a commodious method of warming the water of baths, which, in certain cases of disease, it is of impor-

tance to have near the patient's bed-room; for the boiler, in which the water is heated, may thus be placed on the ground floor, or in the cellar of a house, and the steam conveyed by pipes into an upper apartment. Steam may also be applied to the purpose of heating or evaporating water, by a modification of the apparatus. Fig. 19, plate IV. *g* represents the apparatus for boiling water by the condensation of steam, without adding to its quantity; a circumstance occasionally of considerable importance. The steam is received between the vessel, which contains the water to be heated, and an exterior case; it imparts its caloric to the water, through the substance of the vessel, is thus condensed, and returns to the boiler by the perpendicular pipe. An alteration of the form of the vessel adapts it to evaporation, fig. 18, *h*. This method of evaporation is admirably suited to the concentration of liquids, that are decomposed, or injured, by a higher temperature than that of boiling water, such as medicinal extracts; to the drying of precipitates, &c. In the employment of either of these vessels, it is expedient to surround it with some slow conductor of heat. On a small scale, a few folds of woollen cloth are sufficient; and when the vessel is constructed of a large size for practical use, this purpose is served by the brick work in which it is placed.

Fig. 26 is a section upon a larger scale of the collar joint at *b*, fig. 16, plate IV. made for the convenience of screwing together long or crooked metal tubes, without turning them round. *a* is a section of the end of one of the tubes, and *b* that of the other which is to be attached to it; *c* is a collar which turns loose upon the shoulder of *a* and screws upon *b*. By screwing this collar upon *b*, the end *e e* of the tube *a* is brought to press upon the part *d d* of the tube *b*, without turning round either of

those tubes. If upon *d* be laid a ring of linen cloth, soaked in boiled linseed-oil, the joint, when screwed up, if tolerably well made, will be impervious to steam, as well as to water or air. The projecting at *d* is for preserving the ring of cloth from being displaced, and for guiding the ends of both tubes, so as to meet properly.

A A is a section of a socket, for fixing the stem of a thermometer into a boiler or a digester, where there is much heat and pressure; *b* is a socket, fixed on the outside of the boiler or digester, having a hole through it large enough to admit the bulb of the thermometer; *a* is a plug which screws into *b*, having a hole through its centre large enough to admit only the stem of the thermometer; *c c* is a loose round plate, concave on the upper side, having a hole through its centre just sufficient also to admit the steam of the thermometer.—When the instrument is to be inserted, the plug *a*, and the plate *c*, must both be taken out of the socket. The bulb is then passed through it. The plate *c* is next slipped over the stem, and dropped into its place. Some flax, soaked in linseed-oil, must next be wrapped round the stem, so as nearly to fill the socket. The plug *a* must then be screwed in, till the flax be compressed so as to make the whole sufficiently tight. The opposite surfaces of the plate *c*, and the plug *a*, are made concave, for the purpose of compressing the flax round the stem of the thermometer.

BOLT-HEAD.—This name is given to a spherical glass vessel, flattened a little at the bottom, and provided with a long slender neck. It is chiefly used for making solutions, and for processes of sublimation. Fig. 7, plate IX. is a bolt-head.

In order to sublime any substance, a part of the globe of the bolt-head is surrounded with sand. The matter which is volatilized by the heat, rises, and is condensed against the coldest part of the vessel; where it forms a stratum or cake, that may be taken out by breaking the vessel itself. In this manner it is that corrosive sublimate, calomel, camphor, and other similar products, are formed for the purposes of commerce; the neck of the vessel is loosely stopped.

The heat is most commonly applied through the medium of a sand-bath, and the degree of heat, and the depth to which the vessel is buried in it, are regulated by the nature of the product.

Sublimation is sometimes performed in a crucible, and the vapours are condensed in a paper cone, or in another crucible inverted over it. The process is also conducted in the small way in Florence flasks. For very small quantities of substances common medicine-phials are frequently made use of, and for this purpose set in the sand of a crucible-bath in such a manner that the body sublimed adheres to their prominent and cooler part.

If a small quantity of muriate of ammonia is put into a flask, and heat applied to it, the entire salt rises in the form of white smoke, and condenses in the upper part of the flask, in the form of a crystalline mass, which is a sublimate.

Where a very great heat is required, an earthen retort is the best vessel for sublimation, and the sublimed substance may be collected, either in the cooler extremity of the neck of the retort, or in any receiver beyond it which may be adapted to it. Thus zinc may be distilled from calamine and charcoal, or phosphorus from phosphoric acid and charcoal, simply by dipping the end of

the neck of the retort in water, and the sublimed substance, in either case, concretes partly within the neck and partly in the water. Where the vaporized substance, which is solid when cold, is passed through water, it concretes into a remarkably fine powder, instead of a hard cake, as is usually the case when the receiver is dry. Advantage has ingeniously been taken of late of this circumstance in the preparation of calomel, in the laboratory of Messrs. Howard and Company, to save the labour employed in levigating this important mercurial preparation, for by driving the vaporized calomel through water, it concretes into a powder which scarcely any mechanical operation could bring to equal in fineness.

Sublimation is also occasionally performed either in a retort and receiver, or in an alembic and capital, as will be presently described. This is commonly done where a part of the vaporized substance condenses also into a fluid, which is to be preserved.

Sublimation therefore is a process by which certain volatile substances are raised by heat, and again condensed by cold, into a solid form, hence it differs from distillation only in the form of the product. The formation of soot in our chimnies is an instance of sublimation.

BOTTLE, CAST-IRON, fig. 5, plate XII.—Bottles of this kind are intended for obtaining such gases as cannot be disengaged without exposing the materials from which they are to be produced to a red heat. Fig. 6, a curved tube fitted by grinding. Fig. 11, plate IX. exhibits a cast iron bottle very convenient for obtaining oxygen gas by heat, from per-oxide of manganese, by means of a common fire. Fig. 17, are fluxible metal tubes, fitted by grinding to the mouth of this bottle, these are useful for conveying gas in any direc-

tion, and to any moderate distance. Separate lengths of them may be connected together instantly, and adapted to the retort, gazometer, or other vessel from which gas proceeds. In fig. 6, *a a*, plate V. the use of these tubes is shewn by connecting the air-holders, *b b*, with the gazometer.

BOTTLE, SPECIFIC GRAVITY BOTTLE, fig. 62, plate I.—A small bottle, with perforated tube-stopper, for finding the difference between measures of weight and measures of capacity. For example, when the bottle is filled up to a certain mark in the tube, with distilled water of a given temperature, it should hold exactly 50 or 100 grains, or any even number of grains. The quantity which it is found to contain of any other fluid of the same temperature, denotes the specific gravity of the latter fluid. For example, if it holds 1000 grains of water, and 1850 of sulphuric acid, the specific gravity of the sulphuric acid is to that of water as 1850 to 1000.

BOTTLE WITH RECURVED TUBE FITTED BY GRINDING, fig. 2, plate IX.—This bottle is useful for the production of gases; they are commodious when the evolution of the elastic fluid is not rapid, and the quantity demanded only moderately small. The bottom part of the vessel being made round, and blown thin, renders it not liable to crack by the application of a gentle heat. Bottles of this kind are sometimes tubulated, *b* fig. 18, plate II.—or furnished with an acid-holder as shewn fig. 29, plate I.

BOTTLE WITH TWO NECKS, fig. 13, plate IX.

BOTTLE WITH THREE NECKS, fig. 16, plate IX.—Both these kind of bottles are employed in compound distillation. See **DISTILLATORY APPARATUS, COMPOUND**.

CALORIMETER.—This elegant apparatus is employed for estimating the comparative quantities of caloric contained in bodies. Its action is founded on the fact, that ice or snow, in melting, absorbs always a uniform quantity of caloric: and therefore, by placing a hot body in contact with ice, so that the whole of the caloric it gives out in the reduction of its temperature to 32° , shall be communicated to the ice, and spent in melting it, we may determine, from the quantity of water thus formed, the portion of caloric which has been communicated by the hot body.

This instrument consists of three vessels, fig. 1, plate XIV. *a*, *b*, *c*, adapted to each other, and inserted the one within the other, so as to leave a cavity between the sides of each.

The smallest or innermost, *a*, is a cage of iron network, and is designed to contain the body which is to be subjected to experiment. It is supported by iron hooks *a*, and attached to the internal cavity of the second or middle vessel *b*. This one is designed to contain the ice, from the melting of which the quantity of caloric given out by the body in the first vessel is to be estimated. The ice is broken into small pieces; these are supported on an iron grating *d* fig. 5, at the bottom, through which the water filters, and is conveyed off by a pipe, with a stop-cock, which comes from the bottom of the vessel. It has a double cover, fig. 4, also adapted to it, capable of containing ice; the under part of this being perforated, so that the water, which may be formed from the melting of any of the ice it contains, may drop into the cavity itself. The third, or outer vessel *c*, is similar in its construction to the second, and, like it, is to be filled with pounded ice, when the experiment is to be performed. The design of it is to prevent

the agency of the external atmosphere. It would be inconvenient to operate with this instrument only when the temperature of the atmosphere is at 32° ; but it is obvious, that at temperatures above or below this, a heating or cooling agency would be exerted by the external air on the ice, which is designed to be exposed to the hot body only. If the atmosphere were above 32° , it would communicate caloric to the ice, and of course would contribute to its fusion, and prevent us from ascertaining the quantity of water produced as a measure of the quantity of caloric which the hot body had given out; or if below 32° it would abstract caloric, and lessen the quantity that would otherwise be melted. The design of the outer vessel is to obviate these sources of error, and surround the ice in the middle vessel with a medium at the temperature of 32° . It also has a double cover, fig. 14, containing pounded ice, to serve the same purpose, x is a tube and stop-cock by which the liquid can be withdrawn.

The method of performing the experiment with this apparatus is obvious. The substance on which we are to operate is raised to a certain temperature, which is ascertained, and is then suspended in the innermost cavity, the middle cavity having been previously filled with pounded ice pressed down, so that no void spaces shall remain, and drained so that no water remains mixed with the ice. The caloric it gives out in falling to 32° , is communicated to the ice in this cavity, and melts more or less of it. Lavoisier and La Place calculated from experiment, that one pound of ice in melting absorbs a quantity of caloric which would raise the temperature of water 135 degrees of Fahrenheit, and proceeding on this calculation, by withdrawing the quantity of water produced, and weighing it, it was easy

to ascertain the quantity of caloric which the substance in the reduction of temperature it had suffered had given out; its weight being exactly proportional to the quantity of caloric which the body had given out in its reduction of temperature. By repeating the experiment on different bodies, the comparative quantities of caloric they evolve in passing from one temperature to another, and of course the comparative quantities they contain, were determined. Liquids were introduced in a glass matrass, which was suspended in the cage; the quantity of caloric which the glass would give out, being ascertained by a previous experiment, and airs were operated on, by passing them through a spiral tube, which was fixed in the middle vessel, a thermometer being placed at each extremity of it, to ascertain the temperature of the air as it entered and passed out.

These experiments should be made at a temperature at or a little above 32° , as, below that, the contents of the outer vessel may be entirely frozen, be cooled, and abstract caloric from the middle vessel. Nor should the temperature be more than 10 or 12 degrees above that; for the air included in the instrument, being then heavier than the external air, descends, issues by the tube at the bottom through which the water runs off; and thus a current of air is formed which communicates heat to the ice. The nearer, therefore, the temperature of the external atmosphere is to 32° , the experiment will be more accurate.

The action of the apparatus has been supposed, however, to be liable to some errors, which have rendered it doubtful, whether, on the whole, it is accurate. Two circumstances have in particular been pointed out by Mr. Wedgwood as influencing the results.

The first is, that part of the water formed by melting

of the ice, is retained by capillary attraction in the interstices of the unmelted ice; and hence the quantity that passes off by the tube, at the bottom of the apparatus, is not the proper measure of the quantity actually produced. Lavoisier and La Place were aware of this source of error, but they supposed it could not be of any importance, or might be obviated by strewing the pounded ice in the calorimeter, in thin layers, and allowing it to stand for some time in an atmosphere above 32° , before the experiment was begun. It would thus have imbibed all the water that it could retain by capillary attraction; and therefore the quantity would be the same at the beginning and at the end of the experiment. It is obvious, however, that as in the progress of the experiment, the quantity of the ice, and its arrangement in the vessel must be altered, the portion of water retained by capillary attraction will not be precisely the same, though it is difficult to say to what extent this source of error may operate.

Another more important effect arises from a singular fact, discovered by Mr. Wedgwood, that the operations of thawing and freezing actually go on in the apparatus at the same time, or that part of the water which is melted in the upper part of the middle vessel, in filtrating through the ice, again returns to the solid state. Mr. Wedgwood has very clearly shewn, that this is the case, especially in the lower parts of the apparatus, the fragments of ice thrown in loose being frozen together, so that a passage made through the loose ice is soon nearly filled up.

Fig 2, plate XIV. represents a perspective view of the calorimeter, without its cover, fig. 3 and 4, the wire cage and its cover belonging to the machine.

CAPILLARY DROPPING TUBE, fig. 50, plate I. and fig. 57.—This name is given to a tube of this shape, blown in the middle into a ball, for dropping liquids. The ball is filled by the action of the mouth applied to the upper orifice, while the lower one is immersed in the liquid. To the former the finger is then applied; and, on cautiously removing it, the liquid is expelled in drops; or, when the ball is filled, the water may again be forcibly driven out by the breath: and, if directed against the inner sides of a filtre, will wash down to the bottom every minute particle of the precipitate adhering to it, and thus collect it together.

CAPITAL, fig. 59, plate I.—The upper part or head of the alembic. See **ALEMBIC**.

CAPSUL, fig. 53, plate I.—Capsuls or basons made of glass, in the composition of which no oxide of lead enters, do not easily crack, and stand a low red heat in the sand-bath very well, without bending or losing their shape.

Glass capsules cannot resist the immediate action of fire without incurring almost the certainty of breaking. To prevent this accident, they may be covered with clay lute. In this state the capsul may be used for evaporation, and exposed to the action of a strong and sudden heat without breaking, provided however, the substance they contain be liquid.

When employed with the *sand-bath*, they must be half buried in the sand, in such a manner that the bottom of the vessel may be separated from the fire-place by a bed of sand. The heat of the fire may then be gradually transmitted by the sand; and the refrigeration afterwards takes place by insensible degress, so that the

capsul never receives the sudden impression either of cold or heat, and the operation proceeds with regularity, even when we neglect to keep up the same degree of heat. When the glass capsul is very thin, and of a small size, it may however be safely placed on the ring of the lamp furnace, and the heat of an Argand's lamp, cautiously regulated, may be applied with safety.

Very useful glass capsuls may readily be formed of glass flasks in the following manner: heat a piece of thick iron wire provided with a handle, and apply it red-hot to the part where the separation is to be made, moving it in that direction for the space of three or four lines. The glass cracks with the impression of the heat, and the crack follows the part that is hottest. When the crack begins, pursue it with the iron, bearing upon it. It is best to cleave the glass in the direction of the orifice of the flask, because each capsul is then provided with a spout or beak which is convenient for pouring, decanting, &c.

When the vessel does not split by the first application of heat, communicated by the red-hot iron, the crack may be produced by the application of a wet body to the hottest part, or by throwing a drop of cold water upon it, which will infallibly produce a crack, and which may then be readily extended in the manner above stated.

CAPSUL, GRANULATING CAPSUL, fig. 12, plate IV.
—Two hermespherical cups, made of wood, which accurately screw together, to form a hollow box. The fused metal intended to be granulated is poured into the box, the inside of which should previously be rubbed with chalk. The box is then quickly agitated, till the metal cools, when the rolling motion will be converted into a rattling one. The metal will then be reduced to a fine

granular powder. The adherent chalk is then to be washed away.

CARBOY.—This name is given by chemists to a very large glass vessel, from eight to twelve gallons capacity, and of the form of a compressed globe, with a short neck. It is used by manufacturers for containing sulphuric, nitric, or muriatic acid. It is generally packed into, and protected by, a basket of wicker work.

CASTING CONE, fig. 13, plate VIII.—A metal mould having the form of an inverted cone. When the fusion of substances, that do not unite, or separate during fusion is completed, the melted matter may either be permitted to cool in the crucible, or be poured into a casting cone, by which means the heavier substance collects more readily together into a mass, at the bottom of the vessel. It is usually made of brass, turned smooth within, so that the melted matter does not adhere to the sides of the vessel.

CONDENSING SYRINGE, fig. 33, plate I.—A considerable part of the caloric, which exists in gases in a latent state, may be rendered sensible by rapid mechanical compression. Thus if air be suddenly compressed in the pall of an air-gun, the quantity of caloric liberated by the first stroke of the piston, is sufficient to set fire to a piece of the tinder called *amadou*. A flash of light is also perceptible at the moment of condensation. This fact has been applied to the construction of a portable instrument for lighting a candle. It consists of a common syringe, about six inches long, and $\frac{3}{4}$ of an inch in the bore. At the lower extremity of the piston is a cavity which receives the substance intended to be fired.

The rapid depression of the piston condenses the air, and evolves sufficient heat to set the tinder or *amadou* on fire.

CONDUCTING TUBES, fig. 17, plate IX.—These tubes are very useful for conveying gas in any direction, and to moderate distances. Separate lengths of them may be connected together instantly, and adapted to the retort, gasometer, or other vessel, from which gas proceeds. The tube *a* is furnished with a metal joint at *b*, made air-tight by grinding, this allows the longer extremity of the tube to be put into any direction required.

CRUCIBLE, figs. 11, 12, 13, and 14, plate I.—When solid substances are to be exposed to these intense heats to fuse them, or to favour their mutual chemical action, the vessels, generally employed, at least for experimental purposes, are called crucibles. They are usually of the form of a short truncated inverted cone; some are triangular. Crucibles are made of different materials, according to the purposes for which they are to be used. A crucible ought to support the strongest heat without melting; it ought to resist the attacks of all such agents as are exposed to heat in vessels of this kind.

The Hessian crucibles are composed of clay and sand, they will support an intense heat for many hours, without softening or melting; but they are disposed to crack when suddenly heated or cooled. This inconvenience may be, on many occasions, avoided by using a double crucible, and filling up the interstice with sand, or by covering the crucible with a lute of clay and sand, by which means the heat is transmitted more gradually and equally. Those which give a clear sound when struck,

and are of an uniform thickness, and have a reddish brown colour, without black spots, are reckoned the best. They are sold in nests or sets.

Wedgwood's crucibles, made of porcelain clay, are very excellent for all experimental purposes in the small way. They are very smooth within, and stand a strong heat. They should be coated with fire lute before they are exposed to the action of a very intense heat.

The black lead crucibles, formed of clay and plumbago, are very durable, resist sudden changes of temperature, and may be repeatedly used; but they are destroyed when saline substances are melted in them, and suffer a partial combustion when exposed red-hot to a current of air. They are also very smooth within, so that the melted matters, when poured out, do not adhere to the inside. They are totally unfit for the fusion of alkaline and saline matters, and answer best for metals and metallic substances. They may be used more than once.

Silver crucibles (of perfectly pure silver) are particularly useful in analytical operations, for the fusion of bodies with alcalies, for which platina vessels cannot be employed. The utmost degree of heat they can bear is a moderate redness.

Platina crucibles on account of the absolute infusibility of the metal by the heat of chemical furnaces, and its perfect unalterability by most agents, render the greatest service in the laboratory. They should always be put into a common crucible to defend them from the direct action of the coals, the slack of which affixes itself to the sides and bottom with so much obstinacy, that it cannot be detached without risk of injury to the vessel. But platina is acted upon by fusion by nitrate of potash and also by alcalis. The latter property diminishes

considerably the utility of platina as a medium for crucibles.

Iron crucibles resist heat extremely well; but the air aided by the action of the fire, oxidizes them very speedily, and saline matters readily act upon them; even earths become coloured in iron crucibles, so that they cannot be employed for fusion, except in very few cases.

CRUCIBLE FURNACE, figs. 1 and 2, plate X.—This furnace is made of common black lead crucibles, from 12 to 15 inches high, perforated at the bottom, and supported by a tripod stand, fig. 4. They are covered with an iron plate, into which two holes are cut; the larger hole admits the sand pot, fig. 7, for distillation by the retort, as shewn in the drawings 2. The fuel, which must be charcoal, is put through the smaller hole. The grate, fig. 8, rests on three notches cut at equal distances on the inside of the body of the furnace. These furnaces serve only for moderate heats. Fig. 28, plate XVI. shews the furnace, provided with a sand pot, made of sheet iron. *a a* is a tube traversing the fire for the decomposition of water, &c. The upper part of the crucible is occasionally perforated to admit air when a cover is put on. The iron ring with three hooks, fig. 4, plate X, is to be sunk into the furnace, and on it may be placed retorts, &c. for distillations by the naked fire.

CRUCIBLE STAND, figs. 6, and 7, plate I.—Crucibles should never be set upon the bars of the grate, but always upon a support of the shape represented. The hottest part of a furnace is about an inch above the grate of the furnace. The crucible may be covered, to prevent the fuel or ashes from falling into them, with a lid of the same materials, or a crucible inverted over them. See *a*, fig. 12, plate I.

CRUCIBLE TONGS, figs. 6 and 7, plate VIII.—For removing circular and triangular crucibles out of the fire without danger of breaking them.

CRYOPHORUS.—This name is given by Dr. Wollaston, to the instrument exhibited, fig. 49, plate I. It consists of a glass tube, about 10 or 12 inches long, having an internal diameter of about $\frac{1}{8}$ of an inch, terminated at each extremity by a hollow ball *b*, *c*, one inch in diameter; one of these balls contains about half an ounce of water, and the other is as perfect a vacuum as can possibly be obtained by the glass-blower in the construction of the instrument.

If the empty ball *b*, be kept immersed in a mixture of snow and muriate of lime, or in any other freezing mixture, the water in the ball *c*, will be frozen in a very short time; and this effect takes place, though the ball *c* be two or three feet distance from the empty ball *b*.

CUBIC INCH BOTTLE.—This bottle, which exactly holds a cubic inch, when the stopper is in its proper place, is very convenient for readily ascertaining the specific gravity of fluids in cubic inch capacities. In adjusting the bottle the inch cube of distilled water ought to be taken according to Sir G. S. Evelyn, *Phil. Trans.* v. 88, as corrected by Mr. Fletcher, *Phil. Journ.* vol. 4, equal to 252,506 grains Troy at 60° Fahr. ther. and 29, 5 bar.

CUCURBIT, *a*, fig. 58, plate I.—A wide-mouthed flask of the figure of a gourd, used for various chemical purposes. The body of the glass alembic, *a*, fig. 58, and *a*, fig. 15, plate II. is a cucurbit. It is also called a *body*.

CUPEL, fig. 10, plate I.—Cupels are small cups of the size of the segment of a musket bullet, made of bone ashes very porous; they are principally used in assaying the more precious metals, which are not oxidated by heat and air; any oxidable metal combined with them, soon suffering this change, and the vitrified oxide being absorbed by the cupel. They are placed under an arched earthen vessel, open at the end, named a muffle, fig. 16, plate I., by which, while the fuel is excluded, the air which is necessary in the process, is freely admitted to oxidate the oxidizable metal.

CUPELLING FURNACE, fig. 17, plate XVI.—A table cupelling furnace is made cylindrical, and of black lead strengthened with iron bands. *a* is the opening where the muffle is introduced; it is shewn in the design closed with a door; the charcoal is put in at the door *b* in the dome of the furnace. *c, c*, are openings in which may be inserted the nozzle of a pair of bellows. The furnace is not capable of producing a great heat, unless the fuel be urged violently by a draught of a double bellows. It is also very liable to crack. The two side openings render it useful for other chemical purposes.

CUPEL TONGS, figs. 2 and 3, plate VIII.

DECANTING JAR, figs. 8 and 9, plate XVI.—Tall cylindrical glasses for separating the clear from the turbid part of a fluids, or for separating fluids from solids, which are specifically heavier, especially when the solid is so subtle as to pass through the pores of most substances employed for the filtration of liquids, or so caustic as to corrode them.

DECIMAL WEIGHTS.—A set of weights accurately adjusted, from 1000 grains downwards to $\frac{1}{10}$ of a grain. With these weights the operator has always the same number of weights in the scales as there are figures in the number expressing the weight in grains. Thus, 742, 5 ; grains will be weighed by the weights 700, 40, 2, and $\frac{5}{10}$: and as the error of adjustment is the least possible when one weight is in the scale, that is to say, as a single weight of five grains is twice as likely to be true as two weights, one of two and the other of three grains, because each of these last has its own probability of error in adjustment, the advantages of these weights above the common sub-division is obvious,

DEFLAGERATING JAR, fig. 21, plate IV.—Tall cylindrical glass jar furnished with a wide neck at top. See Air Jar.

DEFLAGERATING LADLE, fig. 20, plate I.—A small ladle rivetted to a long copper wire for containing the combustion of bodies in oxygen gas. It is furnished with a cork *b*, to fit the mouth of the deflagrating jar. The ladle, fig. 21, is furnished with three projecting prongs to inclose the bodies placed into it.

DETONATING TUBE, fig. 54, plate I., and *b*, fig. 16, plate II.—It is frequently an interesting object to pass the electric spark through different kinds of air, either alone or mixed together. In this case a metallic wire is fastened in the upper end of a thick glass tube hermetically sealed at one end, the sides of which, at about the distance of two inches from the sealed end, are perforated with small holes, in which the wires *f, f*, are fixed by cement ; the extremities of which, within

the tube, are distant $\frac{1}{4}$ of an inch. It is made wider at the bottom to stand more steadily. This instrument being filled with water or quicksilver, and inverted, a quantity of the gases intended to be submitted to the action of the electric spark is introduced, so as to depress the fluid an inch or more beneath the wires. The electric spark is made to pass from the one wire to the other, by connecting one of them with the conductor of the common electrical machine, and hanging a chain on the other.

A tube of this kind, when graduated into equal parts, forms Volta's Eudiometer. If, in one of these tubes, we mix 300 parts of common air, and 200 of pure hydrogen gas, there will remain after the explosion excited by passing an electric spark between the two wires *f, f*, about 305 measures. There will, therefore, have been a diminution of 195 measures, of which pretty exactly one third may be estimated to be oxygen. In this instance, therefore, 65 of oxygen have been lost by 300 of air, or 21 and a fraction per cent. The general rule for ascertaining the purity of air by hydrogen gas, in this manner, may be stated as follows: add to three measures of the air under examination, two measures of pure hydrogen gas; inflame the mixture by electricity in the detonating tube; observe the diminution when the vessel has cooled; and, dividing its amount by three, we obtain pretty nearly the quantity of oxygen gas which has been condensed.

Sometimes only one wire is inserted in a perforation in the head of a small tube, and fixed with cement represented fig. 28, plate IV.; it is of such a length as to descend three or four inches within it; and when connected with the electrical machine, the spark issues from its extremity within by the conducting power of

the fluid beneath, which must not, of course, be distant from it more than half an inch.

DIGESTING FLASK, fig. 36, plate I., or **Matrass** Digestion, is commonly performed in glass flasks of this shape, which should only be filled one-third, and covered with a piece of wet bladder, pierced with one or more small holes, so that the evaporation of the fluid may be prevented as much as possible, without risk of bursting the vessel. The vessel may be heated, either by means of the sun's rays, of a common fire, or of the sand bath; and when the last is employed, the vessel should not be sunk deeper in the sand than the portion that is filled. Sometimes, when the menstruum employed is valuable, a distilling apparatus is used to prevent any waste of it. At other times, a blind capital is luted on the flask or matrass, or a smaller flask is inverted within a larger one; and as the vapour which arise is condensed in it, and runs back into the larger, the process in this form it has got the name of circulation.

DISHES, fig. 12, plate XIII.—*a*, fig. 24, plate IV.—It is sometimes required to remove an inverted jar with its contents from the shelf of the pneumatic trough: this is done by the use of a shallow pan or dish, which is immersed in the water of the trough, and the jar is slipped in it; then the whole may be removed, and placed wherever it may be convenient. In this case the shallow pan performs the office of a small trough; and for such purposes several dishes or pans of different sizes should be had in readiness.

DISTILLATORY APPARATUS, SIMPLE.—
See **STILL** and **RETORT**.

DISTILLATORY APPARATUS, COMPOUND.

—This apparatus is one of the greatest improvements that could have been introduced in our laboratories. It not only affords us the means of collecting all the products of a distillation, but also enables us to obtain them separately; it removes all fear of any risk of accident.

In certain cases, the product designed to be obtained by distillation, is an elastic fluid, not condensible by itself, but capable of being condensed by being transmitted through water, with which it is retained in combination. The distillatory apparatus invented by Woulfe, fig. 3, plate XII., is employed for this purpose. It consists of a series of bottles, *b*, *c*, *d*, connected with each other by bent tubes, and connected with a retort, *e*, generally by the medium of a receiver and adopter. The receiver *a*, is designed to collect any condensable part of the product. In the three bottles, water is placed to nearly one half their height, and the tube passing from the one into the other, beyond the second bottle *b*, dips into the water of the bottle into which it is inserted, as is represented in the plate. The gaseous product is thus transmitted through the water, by which, as well as by the pressure which is necessarily exerted by the short column of water in each tube, its absorption is promoted; and if any portion is incapable of being absorbed by the water, it passes off by the bent tube at the end, and may be collected in an inverted jar, in a trough of water. Each of the bottles, except the receiver *a*, has a straight tube, which rises to the height of 8, 10, or 12 inches above its insertion into the bottle, and passes so far within it as to dip in the water nearly half an inch. This tube is termed the tube of safety, and the use of it is to guard against that reflux of fluid which might happen from a partial vacuum arising from con-

densation in any of the bottles. At the commencement of the distillation, the joinings of the tubes with the bottles being well secured, the whole is air-tight; and, by the gas produced, the atmospheric air contained in the upper part of the bottles is in a great measure expelled through the tubes. If, therefore, in any stage of the distillation, the production of gas should diminish, the quantity contained in the bottles being absorbed by the liquor, a partial vacuum is formed; and at the end of the process, when the retort cools, this must always happen: the consequence of this must be, that the water being more pressed on by the atmospheric air without, than by the gas within, must pass backwards from one bottle to another by rising through the tubes, as from *d*, to *c*, and from *c*, to *b*, and thus the whole will be mingled together, which would often defeat the object of the distillation. This, however, is effectually prevented by the tubes of safety, as, when any such partial vacuum happens, the atmospheric air is forced through the small quantity of fluid in which they are immersed, and rising into the bottles, preserves the equilibrium.

Various improvements have been made in this apparatus. One defect in it is, that we cannot have the advantage of the immersion of the tube which comes from the receiver *a*, into the liquid in the second *b*; for, as the receiver, as it sometimes is, is designed to collect the condensable product, and ought therefore to be without water, it can have no tube of safety; and hence, if the tube issuing from it dip into the liquid in the second, whenever any condensation happens, from the gas ceasing to be produced, the liquor will pass backwards into it. The apparatus, therefore, is represented as it ought to be, with the bent tube from the receiver only reaching near the surface of the liquid in the bottle

b, while in the others it is immersed. As the liquid, however, in the bottle *b*, is in the best situation for being impregnated with the gas, and therefore, for forming the most concentrated product, it is of some importance to aid this as much as possible, and obtain the advantage of the gas being forced to pass through it, by the tube passing into it being immersed. The contrivance that has been used for this purpose, is the tube of safety of Welter, or bent tube with an additional curvature, and a spherical ball, represented fig. 25, plate IV., and *b, b*, fig. 9, plate XII., as intermediate between the globular receiver and the common three-necked bottle, and connecting them. In this is put a small quantity of water, so as to rise, when the pressure without and within is equal, about half way into the ball. If the elasticity is increased in the internal part of the apparatus, during the distillation by the production of gas, the water is pressed upwards to the funnel at the top; if there is a condensation, it is forced by the atmospheric pressure into the ball, but whenever it has passed the curvature beneath the ball, it is obvious that a portion of air must rise through it, and will pass into the globe or bottle, to the tube of which this bent tube is adapted. This tube, however, though it answers the purpose effectually, is inconvenient; from its form, it is very liable to be broken; and, what is its principle defect, we can employ no great pressure in the apparatus with it, without making it of such a length as to be unwieldy, and subject to risk. The method employed by Mr. Murray, to obviate this inconvenience, is more simple. It is having the usual bent tube constructed with a ball in that part of it which is inserted in the bottle containing the liquid into which it is to dip, as represented fig. 3, plate VI. By properly proportioning the depth to which

the tube is immersed in the liquid in *b*, to the size of the ball, it is obvious, that when from any condensation in *a*, the liquor in *b*, rises, when the ball is filled, the extremity of the tube will be no longer immersed; a portion of the gas present will therefore rise in it through the water, and preserve the equilibrium, so that if the tube be not too deeply immersed, no part of the liquid in *b*, can ever pass into *a*. This method has the advantages that we can employ any pressure whatever in the apparatus, and that no atmospheric air is introduced in the course of the distillation into the first bottle, but only the elastic fluid which is the product of the process. The use of tubes of this kind may even supersede the use of tubes of safety through the whole apparatus; for, if each have a spherical cavity in its long leg above its insertion in the bottle, and if its immersion in the liquid be duly proportioned, the reflux of the liquid will be prevented, in the manner just now explained, while any extent of pressure may be obtained by a tube issuing from the last bottle being immersed in water or quick-silver.

Another imperfection which attends the common compound distillatory apparatus, is the difficulty of adapting the tubes by grinding, so that it is necessary to secure the joinings by lute, which is always inconvenient. Mr. Murray has remedied this, by having a tube fixed or soldered when the bottle is made, into that orifice into which the long leg of the tube from the preceeding bottle is to enter, as represented fig. 1, plate VI., in the bottles, *b*, *c*, *d*. This soldered tube being of such a length that it is immersed in the liquor within the bottle, and the tube which enters it having a very slight curvature at its extremity, which throws the gas beyond the extremity it cannot return, but must pass forward into the next

bottle; and as there is no difficulty in grinding the tubes into the bottles from which they issue, the whole apparatus is easily constructed without the necessity of lute. The open tube, too, serves the purpose of a tube of safety. The deficiency of an apparatus of this construction, is, that very little pressure can be applied to promote the absorption of the gaseous product by the liquor, as, from the shortness of the open tubes, the liquor, by such pressure, is forced up them, and may overflow; though this may to a certain extent be obviated, by having the wide open tubes not soldered, but ground in, and having them of such a length as will admit of the rise of the liquid, as is represented in *e*. The only difficulty in executing this, is to have the orifice of the bottle into which the wide tube is ground, perfectly straight, and the smaller tube which enters it precisely at a right angle, as otherwise it cannot be inserted, at least without having the wide tube of too great a diameter. With care, however, this may be attained, and the apparatus then answers perfectly well. *a*, is as usual left without water, and therefore cannot have an open tube, but absorption is guarded against, either by the tube passing from it, not dipping in the liquor in *b*, or by having a ball, as represented in the figure.

Fig. 9, plate XII., exhibits the application of compound distillation, in the production of muriatic acid from muriatic of soda by sulphuric acid. The muriate of soda is introduced into the retort, and by means of the bent tube or hydrostatic funnel *a*, the sulphuric acid is added. The receiver *c*, is adapted to the retort by means of an adopter *a*, to receive the portion of impure sulphuric acid and muriatic acid which passes over towards the end of the operation. *d, d*, and *f, f*, are bottles containing water; the quantity of which

should be equal in weight to that of the salt employed. These bottles are furnished with tubes of safety *b, b*.

DISTILLATORY APPARATUS COMPOUND,
(VERTICAL), fig. 8, plate XIII.—This is an useful and safe Woulfe's apparatus, invented by Mr. Knight. *a, b, c, d*, represent four vessels, each ground into the mouth of that below it. *e, e, e*, are glass tubes, the middles of which are ground into the neck of each vessel and of sufficient length to allow the upper end to rise above the liquor, while the lower descends nearly to the bottom of the vessel below. The vessel *a* is kept empty, and serves as a receiver to contain any liquid distilled from the retort which enters at the crifice *f*, and is also furnished with a Welter's tube *g*, to prevent the absorption of any liquid from the lower vessels, when a vacuum is formed by the cooling of the retort or receiver. The vessels *b, c*, and *d*, are filled with the liquor intended to be impregnated with the vapour or gas that distils over, and which passes by the tubes successively through the whole range of vessels. The lower one, *d*, has the bent tube *h* to carry off any unabsorbable gas, and it is made broad and firm at the bottom, besides being fitted into a heavy wooden stand (not here represented), to lessen the danger of being upset. This apparatus unites every requisite, and it has the great advantage of not being easily deranged, and if any part is broken, it may be replaced without much difficulty.

DISTILLATORY APPARATUS COMPOUND,
(PEPYS'S), fig. 9, plate IX.—A very useful alteration in the construction of Woulfe's apparatus has been contrived also by Mr. Pepys. *b*, is a balloon surmounted by a vessel *c*, accurately ground to it, and furnished with

a glass valve, resembling that affixed to Nooth's apparatus. This valve allows gas to pass freely into the vessel, but prevents the water which it contains from falling into the balloon. *a*, is a tubulated retort, joined to a tubulated receiver *b*, into which is fitted, by grinding the pear-shaped vessel *c*, furnished with a valve, constructed by placing a plano-convex lens upon the mouth of a small tube, accurately fitted by grinding, and inserted into the lower aperture of the pear-shaped vessel *c*, and similar to the valve in the well known apparatus of Nooth, but with more water way. From this it is obvious that the gas disengaged from the retort, and which is not absorbed by the fluid contained in the receiver *b*, will, by its upward pressure, raise the valve, and pass into the pear-shaped vessel *c*, without allowing the fluid contained in it to return into the receiver *b*, even when a partial vacuum takes place. The gas which is not absorbed passes into the first three-necked bottle *d*, and if any part should escape absorption by the fluid in that vessel, it passes into the second bottle *e*, or may lastly be conducted into the pneumatic trough by means of the tube *f*.

DISTILLATORY APPARATUS COMPOUND,
(BURKETT'S), fig. 14, plate VII.—*b*, is a tubulated receiver, to which, in the usual manner, is joined a retort, and from which a bent tube, *c*, passes to the second receiver *d*. This last communicates with the bottle *f*, by means of the bent tube *c*. The end of the tube *b*, which enters the receiver *d*, is furnished with a valve which prevents the return of any gas from the receiver *d*, to the receiver *b*, in case a vacuum should take place in the course of the operation in the receiver *b*, or in the

retort. The valve is the most defective, because it is liable to be set fast in making chlorate of potash, or any other crystallisable salt.

DISTILLATORY APPARATUS, COMPOUND,
(HAMILTON), fig. 7, plate III.—Is a very convenient apparatus for impregnating fluids with gases. It consists of three parts; *a* is a tubulated retort, with a short thick neck, fitted accurately into the lateral opening *x* of the two-necked bottle *b*. The upper pear-shaped vessel *c*, is ground air-tight into the two-necked bottle *b*; it has a long glass tube, (as shown in the design,) reaching to the bottom of the two-necked bottle *b*. The use of this apparatus is as follows:—A quantity of water to be saturated with gas is put into the bottle *b*. The influx of gas from the retort accumulating at the top of *b*, drives the fluid up to the tube *d*, into the pear-shaped vessel *c*, till the two-necked vessel *b* is empty of water, and only filled with gas, on which a considerable pressure is therefore always kept up. The substances from which the gas is to be procured, are put into the retort *a*, which is represented resting upon a wooden stand. This apparatus is very useful for making liquid oxy-muriatic acid, sulphurous acid, &c. The spirit lamp *y*, being applied, as shown in the design.

DISTILLATORY APPARATUS, COMPOUND,
FOR PREPARING LIQUID CHLORINE, fig. 8, p. III.
The muriate of soda and oxyd of manganese are introduced into the long-necked matrass *A*, which is placed on a sand bath. This matrass is shut with a cork-stopper *B*, pierced with two holes, into one of which is inserted the tube *D*, bent at *E*, and terminating at the upper extremity

in a funnel F, by means of which the sulphuric acid is introduced into the matrass. The other hole of the stopper B, receives the extremity of a tube G, which forms a communication between the matrass and the flask with three tubulures H, containing one-eighth of its contents of water, and into which is inserted a tube of safety K, to prevent absorption. This flask H, is connected with another vessel P, by the tube N. The vessel P is half full of water, and has a communication with a second flask furnished with a tube of safety; and this second flask has a communication with a third, &c. All the joinings must be well secured by fat luting, covered with a bandage of linen daubed over with the white of an egg and lime; the matrass is then to be gradually heated.

As chlorine is not easily condensed, a large quantity of water contained in several vessels, or disposed in the form of a very high column, is presented to it, in order that, by compressing the gas and obliging it to pass through a longer space, it may be more readily absorbed.

If the flasks be surrounded with ice, the chlorine crystallizes at the temperature of zero.

DIFFERENTIAL THERMOMETER, fig. 1, plate XIII.—This instrument, for which we are indebted to Mr. Leslie, is calculated for measuring very minute variations of temperature. The Differential Thermometer consists of two glass tubes, each terminating in a small bulb A. B. of the same dimensions, and bent in the form of an U, a small portion of dark coloured liquor (sulphuric acid, tinged red with carmine,) having previously been introduced into one of the balls. By managing the included air with the heat of the hand, this red liquor is made to stand at the point required of the opposite tube. This is the zero of a scale

fastened to that tube, and divided into equal parts above and below nothing. It is manifest, that when the liquor is at rest, or points at zero, the column is pressed opposite ways by two portions of air, equal in elasticity, and containing equal quantities of caloric. Whatever heat then may be applied to the whole instrument, provided both bulbs receive it in the same degree, the liquor must remain at rest. But if the one ball receives the slightest excess of temperature, the air which it contains will be proportionably expanded, and will push the liquid against the air in the other bulb with a force, as the difference between the temperatures of those two portions of air. The equilibrium, in short, will be destroyed, and the fluid will rise in the opposite tube. The degrees of the scale through which it passes will mark the successive augmentations in the temperature of the ball, which is exposed to the greatest heat. This instrument, therefore, is truly a balance of extreme delicacy, for comparing the temperatures with which its two scales may be loaded. It is not at all influenced by any variation of temperature in the surrounding medium, is peculiarly calculated for experiments on radiant caloric: it combines great delicacy with accuracy. The differential thermometer, as its name expresses, announces not the absolute degree of heat, but the difference (when any exists) between two given spots where the thermometer is made to act. A moment's attention to the construction of the instrument, which is in fact a double air thermometer, separated by a portion of intercluded fluid, will shew that it indicates only the difference of heat of two contiguous spots. As long as the elasticity of the air in one leg is equal to that in the other, the air contained in both balls will have the same elasticity, and the liquor in each tube or leg will be equally pressed on in opposite directions, and will remain sta

tionary at a certain height. If the instrument, for instance, be introduced either into a warmer or colder atmosphere, the temperature of both balls will be equally affected; the volume of air in each will be equally expanded or contracted, and hence the liquor will still remain stationary. But, if one of the balls be more heated or cooled than the other, this equilibrium will be subverted, the superior elasticity of the confined air of the ball, which is exposed to a warmer air, will drive the interposed liquor forwards, and make it rise in the tube connected with the ball which is at the lower temperature, and of course fall in the other; and hence the instrument is calculated to point out the *difference* of temperature in the corresponding balls; this it will do with peculiar nicety.

DROPPING TUBE, fig. 56 and 57, plate I.—The hollow ball of this tube is filled by the action of the mouth applied to the upper orifice whilst the lower one is immersed in water. When the ball is filled, the water may again be forcibly driven out by the breath; and if directed against the inner sides of the filtre, will wash down to the bottom; every minute particle of a precipitate adhering to it, may thus be collected together.

EUDIOMETER, (PRIESTLEY'S).—No sooner was the composition of the atmosphere known, than it became an inquiry of importance to find out a method of ascertaining with facility and precision the relative quantity of oxygen gas contained in a given bulk of atmospheric air.

The instruments in which the oxygen gas of a determined quantity of air was ascertained, received the name of **EUDIOMETERS**, because they were considered as measurers of the purity of air, they are however more properly called **OXIMETERS**. These instruments have in our

own times become of great importance in Experimental Chemistry.

The first Eudiometer, figs. 25, 26, and 39, plate I., was made in consequence of Dr. Priestley's discovery, that when nitrid oxyd is mixed with atmospheric air over water, the bulk of the mixture diminishes rapidly, in consequence of the combination of the gas with the oxygen of the air, and the absorption of the nitric acid thus formed by the water.

When nitric oxyd is mixed with nitrogen gas, no diminution takes place; but when it is mixed with oxygen gas in proper proportions, the absorption is complete. Hence it is evident, that in all cases of a mixture of these two gases, the diminution will be proportional to the quantity of the oxygen. Of course it will indicate the proportion of oxygen in air; and by mixing it with different portions of air, it will indicate the different quantities of oxygen which they contain, provided the component parts of air be susceptible of variation. This Eudiometer consists simply of a graduated glass tube from half an inch to one inch in diameter, either with or without a foot, (fig. 39, plate I.) and from 10 to 15 inches high, open at one end and closed at the other.

The mode in which Dr. Priestley employed it was extremely simple. One ounce measure was filled with the air designed to be submitted to trial, and this was introduced into a jar of $1\frac{1}{2}$ inch in diameter, inverted in water; the same measure of nitrous gas newly prepared was added to it; and the mixture was allowed to stand two minutes. If the diminution of volume were considerable, more nitrous air was added, till the oxygen in the air submitted to examination appeared to be saturated. The whole was then transferred into a glass tube about two feet long, and half an inch wide, graduated according to the air mea-

sure, and divided into tenths and hundredth parts. The space occupied by the residuum was thus measured, and compared with the volume of airs mixed, so that the diminution was visible by inspection: and as one measure of oxygen gas, according to Priestley, is condensed by two measures, or rather by 1.97 of nitric oxyd gas, or nitrous gas, the quantity of diminution is divided by 3 or 2.97 to give the volume of oxygen gas. It is essential that as much nitric oxyd gas be employed as will decompose the quantity of oxygen operated upon; and it is adviseable to use a slight excess. Thus, if atmospheric air is analysed by nitric oxyd add, 100 measures of it to 50 measures of nitric oxyd gas in a jar of $1\frac{1}{2}$ inch diameter, the whole will be condensed to 84 measures; the diminution therefore is 66, which divided by 3, gives 22 as the volume of oxygen gas.

M. Dalton has remarked, that in using nitric oxyd the experiment to procure an accurate result ought to be conducted in such a manner as to form either nitric acid or nitrous acid, and avoid the intermediate proportions, as these must be variable. Now, this depends principally on the proportions in which the gases are mixed, and the more or less free admission of water. Of the two modes, that in which the influence of water is excluded, except in so far as to condense the product, in which case nitric acid is formed, is, according to Mr. Dalton, most easily and most accurately effected. "In order to this, a narrow tube is necessary; (fig. 39 or 26, plate I.) one just wide enough to let air pass water, without requiring the tube to be agitated, is best. Let little more nitric oxyd gas than is sufficient to form nitric acid be admitted to the oxygenous gas; let no agitation be used, and as soon as the diminution appears to be over for a moment, let the residuary gas be transferred

to another tube, and it will remain without any further diminution of volume. Then $\frac{7}{19}$ ths of the loss will be due to oxygen." In making the experiment, therefore, on atmospheric air, add 36 measures of nitric oxyd gas to 100 of air; avoid agitation; ascertain the diminution of volume; and multiplying this by $\frac{7}{19}$, the product gives the proportion of oxygen.

Gay-Lussac has recommended the opposite mode, and has affirmed, that in a narrow tube, and without a considerable excess of nitric oxyd, the results are variable. He employs a very wide jar, fig. 17, plate XII., and having put in it 100 measures of atmospheric air, he adds 100 measures of nitric oxyd gas. A dense red vapour is immediately produced, which disappears without agitation, and in a minute or little more the absorption is complete. The residual gas is transferred into a graduated tube, the degrees of which correspond with the measures of the gases employed. The absorption, according to Gay-Lussac, is uniformly about 84 parts, the fourth of this (according to his assumption that three measures of oxygen combine with one of oxygen, to form nitrous acid) gives the volume of oxygen, or 21 in 100 parts of atmospheric air. The combination of nitric oxyd with oxygen being so much influenced, however, by circumstances, the experiment may be liable to give discordant results, in the hands of different experimentalists.

EUDIOMETER, (PEPY'S).—In this apparatus a solution of hydrosulphuret of potash, or muriate of iron, impregnated with nitrous gas is employed as the Eudiometric liquid. It is put into an elastic gum bottle, fig. 11, plate XI., which is connected with a graduated tube (similar to fig. 39, plate I.) containing the air to be examined; by pressing the bottle, the liquid is made

to act on the air with a degree of compression, which favours the result. The method is rather complicated. It affords, however, a useful instrument for separating other aëriform fluids from each other, and ascertaining their purity, especially when liquids have to be used for these purposes at a high temperature.

EUDIOMETER, (SCHEELE'S,) is merely a graduated glass cylinder, containing a given quantity of air, exposed to a mixture of iron filings and sulphur formed into a paste with water. The substances may be made use of in the following manner :

Make a quantity of sulphur in powder, and iron filings, into a paste with water, and place the mixture in a saucer or plate, over water on a stand raised above the fluid; then invert over it a graduated bell-glass, and allow this to stand for a day or two. The air contained in the bell-glass will gradually diminish, as will appear from the ascent of the water.

When no further diminution takes place, the vessel containing the mixture must be removed, and the remaining air will be found to be nitrogen gas, which was contained in that quantity of atmospheric air.

The error to which this method is liable, is, that the sulphuric acid which is formed acts on the iron, and produces hydrogen gas, which joins to the nitrogen remaining after the absorption, and occasions an incorrect result; and hence it is that the absorption amounts in general to 0.27 parts, although the true quantity of oxygen is no more than from 0.21 to 0.22.

EUDIOMETER, (DE MARTI'S.)—De Marti obviated the errors to which the method of Scheele was liable. He availed himself for that purpose of a hydrogenated

sulphuret, formed by boiling sulphur and liquid potash, or lime water, together. These substances, when newly prepared, have the property of absorbing a minute portion of nitrogen gas; but they lose this property when saturated with that gas, which is easily effected by agitating them for a few minutes in contact with a small portion of atmospheric air.

The apparatus is merely a glass tube, ten inches long, and rather less than half an inch in diameter, open at one end, and sealed at the other. The close end is divided into 100 equal parts, having an interval of one line between each division. The use of this tube is to measure the portion of air to be employed in the experiment. The tube is filled with water, and by allowing the water to run out gradually while the tube is inverted, and the open end kept shut with the finger, the graduated part is exactly filled with air. These hundred parts of air are introduced into a glass bottle filled with liquid sulphuret of lime, previously saturated with nitrogen gas, and capable of holding from two to four times the bulk of the air introduced. The bottle is then to be closed with a ground glass stopper, and agitated for five minutes. After this the stopper is to be withdrawn while the mouth of the phial is under water; and for the greater accuracy it may be closed and agitated again. Lastly, the air is to be again transferred to the graduated glass tube, in order to ascertain the diminution of its bulk.*

EUDIOMETER, (HUMBOLT'S.) Humbolt's method of analysing air, consists in decomposing a definite quantity by means of the combustion of phosphorus, after

* Journ. de Phys. LII. 176.

which the portion of gas which remains must be measured.

Take a small glass cylinder closed at the top, and whose capacity must be measured into sufficiently small portions by a graduated scale fixed on it, fig. 17, plate XI. If the instrument be destined solely for examining atmospheric air, it will be sufficient to apply the scale from the orifice of the cylinder down to about half its length, or to sketch that scale on a slip of paper pasted on the outside of the tube, and to varnish it over with a transparent varnish.

This half of the eudiometrical tube is divided into fifty equi-distant parts, which in this case indicate hundredth parts of the whole capacity of the instrument.

Into this vessel, full of atmospheric air, put a piece of dry phosphorus (one grain to every twelve cubic inches,) close it air-tight and heat it gradually, first the sides near the bottom, and afterwards the bottom itself. The phosphorous will take fire and burn rapidly. After every thing is cold, invert the mouth of the eudiometer-tube into a basin of water or mercury, and withdraw the cork. The water will ascend in proportion to the loss of oxygen gas the air has sustained, and thus its quantity may be ascertained.

EUDIOMETER, (Dr. HOPE'S), fig. 15, plate X. It consists of a small bottle, of the capacity of 20 or 24 drachms, destined to contain the eudiometric liquid, and having a small stopper at *b*. Into the neck of the bottle a tube is accurately fitted, by grinding, which holds precisely a cubic inch, and is divided into 100 equal parts. To use the apparatus, the bottle is first filled with hydrosulphuret of lime, which is best prepared by boiling a mixture of lime and sulphur with water, filtering the soluti

and agitating it for some time in a bottle half filled with common air. The tube, filled with the gas under examination, (or with atmospherical air, when the quality of this compound is to be ascertained), is next put into its place; and, on inverting the instrument, the gas ascends into the bottle, where it is brought extensively into contact with the liquid, by brisk agitation. An absorption ensues; and, to supply its place, the stopper *b* is opened under water, a quantity of which rushes into the bottle. The stopper is replaced under water; the agitation renewed; and these operations performed alternately, till no further diminution takes place. The tube *a* is then withdrawn, the neck of the bottle being under water, and is held inverted in water for a few minutes; at the close of which the diminution will be apparent. Its amount may be measured by a graduated scale marked on the tube.

EUDIOMETER, (SEGUIN'S), consists of a glass tube of about one inch in diameter, and eight or ten inches high, closed at the upper extremity. It is filled with mercury, and kept inverted in this fluid in the mercurial trough. A small bit of phosphorus is introduced into it, which, on account of its specific gravity being less than that of mercury, will rise up in it to the top. The phosphorus is then melted by means of a red-hot poker, or burning coal applied to the outside of the tube. When the phosphorus is liquified, small portions of air destined to be examined, and which have been previously measured in a vessel graduated to the cubic inch or into grains, are introduced into the tube. As soon as the air which is sent up reaches the phosphorus, a combustion will take place, and the mercury will rise again. The combustion continues till the end of

the operation; but for the greater exactness, Mr. Seguin directs the residuum to be heated strongly. When cold it is introduced into a small vessel, whose capacity has been ascertained at the same time as that of the preceding. The difference of the two volumes gives the quantity of the oxygen gas contained in the air subjected to examination.

EUDIOMETER, (BERTHOLET'S).—Instead of the rapid combustion of phosphorus, Bertholet has substituted its spontaneous combustion, which absorbs the oxygen of atmospheric air completely, and when the quantity of air operated on is small, the process is accomplished in a short time.

Bertholet's apparatus consists of a narrow graduated glass tube, fig. 26, plate I. containing the air to be examined, into which is introduced a cylinder or stick of phosphorus supported upon a glass rod, while the tube stands inverted in water. The phosphorus should be nearly as long as the tube. Immediately after the introduction of the phosphorus, white vapours are formed which fill the tube; these vapours gradually descend and become absorbed by the water. When no more white vapours appear, the process is at an end, for all the oxygen gas which was present in the confined quantity of air, has united with the phosphorus; the residuum is the quantity of nitrogen of the air submitted to examination.

This eudiometer, though excellent of the kind, is nevertheless not absolutely to be depended upon; for as soon as the absorption of oxygen is completed, the nitrogen gas exercises an action upon the phosphorus, and thus its bulk becomes increased. It has been ascertained that the volume of nitrogen gas is increased to $\frac{1}{40}$ part; consequently the bulk of the residuum diminished

by $\frac{1}{40}$ gives us the bulk of the nitrogen gas of the air examined; which bulk subtracted from the original mass of air, gives us the proportion of oxygen gas contained in it. The same allowance must be made in the Eudiometer of Seguin.

EUDIOMETER, (DAVY'S).—This Eudiometer requires little address, and is very expeditious; the apparatus is portable, simple, and convenient.

Take a small glass tube, fig. 39, plate I. graduated into one hundred equi-distant parts; fill this tube with the air to be examined, and plunge it into a bottle or any other convenient vessel, containing a concentrated solution of green muriate, or sulphate of iron, strongly impregnated with nitrous gas. All that is necessary to be done is to move the tube in the solution a little backwards and forwards; under these circumstances the oxygen gas contained in the air will be rapidly absorbed, and condensed by the nitrous gas in the solution, in the form of nitrous acid.

The state of the greatest absorption must be marked, as the mixture afterwards emits a little gas which would alter the result.

This circumstance depends upon the slow decomposition of the nitrous acid (formed during the experiment) by the green oxyd of iron, and the consequent production of a small quantity of aëriform fluid (chiefly nitrous gas); which having no affinity with the red muriate, or sulphate of iron, produced by the combination of oxygen, is gradually evolved, and mingled with the residuual nitrogen gas.

The impregnated solution with green muriate is more rapid in its operation than the solution with green sulphate. In cases when these salts cannot be obtained in a state

of absolute purity, the common sulphate of iron of commerce may be employed. One cubic inch of moderately strong impregnated solution is capable of absorbing five or six cubic inches of oxygen in common processes; but the same quantity must never be employed for more than one experiment.

EUDIOMETER, (VOLTA'S).—See Detonating Tube, page 87.

EVAPORATING BASIN, fig. 65, plate I. fig. 12, plate XII.—Evaporation is used for separating volatile fluids from those which are fixed in the same degree of heat. It is therefore performed by the application of heat, and it is promoted by using shallow vessels, and extending the surface of the fluid as much as possible. The object of evaporation is to concentrate a solution, by the subtraction of a portion of the liquid, in order to obtain separately the substance which is in the liquid. The basin should present an extensive surface, proportioned to the depth of liquor, and admit of it being quickly heated, and of the vapour escaping without any resistance. Evaporating basins are of glass, earthen-ware, or metal, according to the substances operated on, and the degree of heat which is to be applied. In chemical experiments, on a small scale, basins of glass, or of Wedgwood's ware, are employed. The latter are the most convenient. Their flat-bottomed shape permits them to be heated more readily than those of glass, which cannot be made so shallow; and as the mass of the liquid intended to be evaporated has little depth and a proportional large surface, the evaporation takes place very rapidly. They may be placed over a lamp without much risk of cracking.

There is no particular kind of evaporating vessel which can be adapted exclusively on all occasions. It may only be observed, that glass presents the greatest number of advantages, because it is composed of a substance the least attacked, the least soluble, and the least destructible by chemical agents. The larger sized porcelain biscuit evaporating basins, (we mean such as hold at least one gallon,) are usually made with the sides more upright, or nearly semi-globula, fig. 5, plate V., and hence they are more liable to crack than shallow ones. Evaporating vessels of glass, or porcelain, when of a moderate size, are generally bedded, up to their edge, in sand, fig. 10 and 16, plate XVI., and fig. 64, plate I.; but those of various metals are placed immediately over the naked fire. Evaporatory vessels of gold, of silver, or of platina, are to be preferred in some delicate operations; but the price of these vessels do not permit them to be used, especially in the large way.

FILE, fig. 2, plate II.—*Rat-tailed* files are convenient for perforating corks, into which glass tubes are to be cemented, without much danger of splitting the cork.

FILTRING STAND, fig. 19, plate I. fig. 2, plate IV. fig. 26, plate XVI. fig. 5, plate VII.—*Filtration* is a finer species of sifting. It is sifting through the pores of paper, or flannel, or fine linen, or sand, or pounded glass, or porous stones, and the like; but it is used only for separating fluids from solids, or such parts that may happen to be mechanically suspended in them, or not chemically combined with the fluid. Thus salt water cannot be deprived of its salt by filtration; but muddy water may.

The filtrirg stand, fig. 19, plate I. consists of three legs

supporting an horizontal board, furnished with a hole, for supporting a funnel.

For the nicer purposes of Chemistry, bibulous paper must be used folded up into a conical form *a*, and placed within a funnel; it should be colourless, which may be easily obtained, and therefore not the blotting paper of ordinary use. In other preparations, linen, woollen, or cotton cloths, may be employed, which allow the liquid to pass readily through them, and which, therefore, are especially applicable to solutions of vegetable matters, and separation of them from their insoluble parts when required for immediate use. Very acrid liquors, such as acids, are filtred by means of a glass funnel, filled with powdered quartz, a few of the larger pieces being put in the neck, smaller pieces over these, and the fine powder placed over all. The porosity of this last filter retains much of the liquor; but it may be obtained by gently pouring on it an equal quantity of distilled water; the liquor will then pass through, and the water will be retained in its place. The filtrig stand, fig. 26, plate XVI., is furnished with a drawer *a*, for containing filtrig paper, and a sliding board *b*, which may be elevated at different heights.

FILTRING FOUNTAIN, fig. 5, plate VII.—Water may be filtrated in large quantities through a stratum of gravel and charcoal, placed in a curved pipe, so that it must rise upwards through the stratum; fig. 5, plate VII., exhibits the arrangement. The gravel, or sand and charcoal, is placed in the curved pipe B, the water passes in at A, and is discharged at C. Another simple apparatus of this kind is a barrel, divided perpendicularly, by a board perforated with a row of holes along the lower

edge. Into each side, as much well washed sand is put as will cover these holes an inch or two, over which must be placed a layer of pebbles to keep it steady. The apparatus is now fit for use. Water poured into the one half will sink through the sand in that side, pass through the holes in the division to the other, and rise through the sand in the other half, from which it may be drawn by a stop-cock.

FILTRING BAG, fig. 1, plate II.—The size of filters must depend on the quantity of matter to be strained. Hence when large flannel or linen is formed into a conical bag, and suspended from a hoop, fig. 1, plate II., *a, a*, or frame, the paper is spread on the inside of the bag. It is of advantage to introduce strings of pack-thread, or a few pieces of straw between the paper and the bag, to prevent the paper from adhering too closely.

What passes first is seldom fine enough, and must be poured back again, until by the swelling of the fibres of the filter, or filling up of its pores, the fluid acquires the requisite degree of limpidity. The filter is sometimes covered with charcoal powder, which is a useful addition to muddy and deep-coloured liquors. The filtration of some viscid substances is much assisted by heat.

FILTRING FRAME, fig. 9, plate VIII.—Where no extraordinary nicety is required, the readiest way of filtering large quantities of fluid is, to throw them on a linen cloth covered with filtering paper, supported by a frame of this kind. Elutrition is a species of filtration; it is confined to such mineral substances on which water has no action. It is performed for separating them from foreign articles and impurities of a different specific gravity, in which case they are said to be washed; or for

separating the impalpable powders obtained by trituration and levigation from the coarser particles. This process depends upon the property that very fine or light powders have, of remaining for some time suspended in water. It is performed by diffusing the powder or paste, formed by levigation, through plenty of water, in a tall cylindrical vessel, letting it stand a sufficient time until the coarser particles settle at the bottom, and then pouring off the liquid in which the finer or lighter particles are suspended. Fresh water may be poured on the residuum, and the operation repeated: or the coarser particles which fall to the bottom may be previously levigated a second time.

FLASK, (DIGESTING FLASK.)—When the solution or digestion of a substance in a fluid is quickly to be effected, the bottle fig. 36, plate I., or fig. 6, with a round bottom, may be used. A common Florence oil flask serves the same purpose extremely well, and bears, without cracking, sudden changes of temperature; being blown thin and equable, it sustains alterations of temperature with less risk of breaking, and from its long neck any vapour which is formed is condensed and falls back.

The vessel when employed for digestion or solution, should not be above $\frac{1}{3}$ full. It should be tied over with a piece of wet bladder, and pierced with one or more small holes made with a pin, so that the evaporation of the fluid may be retarded as much as possible. The flask may be heated over the lamp-furnace. Solution is accelerated by shaking and agitating the mixture. Perfect transparency and permanent suspension of the solid are marks of perfect solution, by which it is distinguished from simple mixture, or mechanical diffusion. The chemist should be provided with flasks of different sizes;

narrow mouthed flasks, fig. 36, plate I., are best for the processes of digestion, and also for obtaining gases; the production of which does not require the aid of a strong heat, such as carbonic acid, hydrogen, sulphuretted hydrogen, chlorine, &c.; for instance let us suppose that we wish to procure carbonic acid gas, by means of the contrivance represented, fig. 17, plate II., which consists of a common earthenware basin, across the rim of which is placed a wooden board, four or five inches wide, and about three-fourths of an inch thick, having a slit terminating in a hole, cut in the centre of the board, which hole serves to receive an inverted common quart bottle as shewn in the drawing. The flask is furnished with a glass tube which connects the two bottles and serves to convey the gas, from the flask to the bottle, for one extremity of the tube passes air tight through the cork in the neck of the bottle, whilst the other end is inserted into the neck of the inverted bottle. To impregnate water with carbonic acid gas (or with any other gas which is not absorbable by water) by means of this apparatus, let the quart bottle be filled with water, quite full, stop it with a cork, and invert it, with its neck downward, into the earthenware basin, also previously filled with water, and let it rest in the centre hole of the board, as represented in the design, and then withdraw the cork. This being done, put some white marble, lime-stone, or common chalk, broken into pieces of the size of a pea, into the flask, and pour upon it common muriatic acid diluted with two or three times its bulk of water: the carbonic acid gas, which becomes extricated by the action of the acid upon the marble, will pass through the bent glass tube and enter the quart bottle from which it expels the water, and the bottle thus becomes filled with carbonic acid gas. When this has been effected, cork the bottle,

in its inverted position, with its neck under the surface of the water: and having next removed it out of the basin, pour into it about half a pint of distilled water, cork it again perfectly air-tight, shake it for about three or four minutes, and then suffer it to stand for two or three hours, taking care to agitate it during that time frequently. The water will thus become strongly impregnated with carbonic acid gas, it will send forth a multitude of air bubbles when exposed to the air, and particularly when poured from one vessel into another, or when gently warmed. The colder the water is, the more carbonic acid gas will be absorbed.

It is obvious that a quantity of carbonic acid gas, equal to the portion of water poured into the bottle, is wasted, but this is not an object, and this loss may even be avoided by inverting the bottle filled with carbonic acid gas, into a small cup containing distilled water, and suffering it to stand a few hours, or till a sufficient quantity of the water has ascended into the bottle, and has become impregnated with the gas.

FLASK, for weighing gases, fig. 3, plate I.—The method of weighing gases is very simple and easily practised. For this purpose, however, it is necessary to be provided with a good air pump; and with a flask of very thin glass, furnished with a brass cap and stop cock, as shown fig. 3, plate I.; or instead of the flask, a glass globe furnished with a brass cap and stop cock, fig. 43, plate I., or *a*, fig. 2, plate XI., may be used. A receiver, *e*, fig. 2, plate XI., is, also, required, to which a stop cock is adapted, as shown in the design.

Supposing the receiver *e* to be filled with any gas, the weight of which is to be ascertained, we screw the cock of the glass globe *a*, or of the flask fig. 3, plate I., on the transfer plate *x* of an air-pump, and exhaust it as completely

as possible. The weight of the exhausted vessel is then very accurately taken, even to a small fraction of a grain; and it is screwed upon the stop cock of the receiver *e*, fig. 2, plate XI. On opening both cocks, the last of which should be turned very gradually, the gas ascends from the vessel *e*; and the quantity, which enters into the flask or globe, is known by the graduated scale on the receiver *e*. On weighing the flask a second time, we ascertain how many grains have been admitted. If we have operated on common air, we shall find its weight to be at the rate of about 31 grains to 100 cubical inches. The same quantity of oxygen gas will weigh about 34 grains, and of carbonic acid gas upwards of 47 grains.

In experiments of this kind it is necessary either to operate with the barometer at 30 inches, and the thermometer at 60° F. or to reduce the volume of gas employed to that pressure and temperature. Great care is to be taken, also, not to warm any of the vessels by contact with the hands, from which they should be defended by a glove. On opening the communication between the receiver and the exhausted globe or flask, if any water be lodged in the stop-cock attached to the former, it will be forcibly driven into the latter, and the experiment will be frustrated. This may be avoided by using great care in filling the receiver with water, before passing into it the gas under examination. *d* is a female joint for connecting the two male cocks of the receiver *e*, and the flask or globe *a*.

FLASK, WIDE MOUTH, fig. 24, plate I., fig. 60, plate I., and fig. 1, plate I.—Wide mouthed flask, for connecting with the mouth of the flask, glass tubes, or other chemical apparatus, see thus, fig. 24, plate I., forms a convenient contrivance for collecting ammoniacal gas, without the aid

of a mercurial trough, as well as other gases, which cannot be collected over water, on account of being rapidly absorbed by it; its action is founded on the difference between the specific gravity of the gas, and that of common air. Thus, ammoniacal gas, which is much lighter than common air, may be obtained in the following manner:

Take the flask, *a*, fig. 24, plate I., put into it a mixture of equal parts of slacked quicklime and muriate of ammonia, previously separately reduced to a fine powder; adapt to the mouth of the flask a cork *b*, into which is firmly fixed, and secured with sealing-wax, a straight glass tube *c*, of about a $\frac{1}{4}$ of an inch in diameter, and invert over this tube the receiver or bell glass *d*, in such a manner that the upper extremity of tube *c* reaches close to, or touches, the top of the receiver *d*, and then apply to the bottom of the flask a gentle heat, by means of a spirit lamp. The ammoniacal gas will thus be produced; and being much lighter than common air, and directed to the top of the receiver, it will expel the common air gradually out of the receiver *d*, and occupy its place. We will know when the receiver or bell glass, *d*, is filled with the gas, by a dense vapour being instantly produced, when a feather, or glass rod, moistened with muriatic acid, is brought near to the open end of the receiver.

Fig. 1, plate I., exhibits two wide-mouthed glass flasks put mouth to mouth, they are convenient for showing the action of various gases upon each other; for example—the production of muriate of ammonia, by the union of muriatic acid gas; the production of nitrous acid, by the mixture of nitrous gas and oxygen, &c.

FORGE.—The common smith's forge which needs no description, is of great convenience for the practical

operations of the laboratory; indeed, the modern discoveries made in philosophical chemistry have rendered this machine a particularly necessary appendage to every well regulated laboratory. To obtain the metals from the alcalies and earths, &c. the forge-hearth is very handy. By means of it long tubes may be exposed in a ready way, to an intense heat, whilst the operator, at the same time, is enabled to take them away from the fire quickly and to replace them instantly at pleasure, a circumstance which cannot be accomplished in any close furnace whatever. For the smelting of metallic ores, the forge is by far the readiest and most commodious contrivance.

The blow-pipe, when adapted to the double bellows of the instrument, is well suited for the purposes of blowing and blending glass, by directing the blast of air through a large skein of cotton, supplied for combustion with melted tallow. Even to kindle a fire quickly the forge is extremely useful; and by connecting a flexible leather tube to the blast-pipe of the bellows, a stream of air may be introduced into any furnace of the laboratory where a rapid blast is wanted. The small oblong trough attached to the forge-hearth, is convenient to hold hammers, pincers, and other instruments; when filled with water it serves as a bath for tempering iron or steel. As the smoke of the forge fire is very considerable, if common coal be employed, it is advisable to have a funnel-shaped sheet iron, or brick hood, over the fire, to carry away the smoke into the chimney. If dense coke, or coke and charcoal, be used as fuel, the hood is unnecessary.

FORGE FURNACE.—*See* FURNACE.

FREEZING APPARATUS, fig. 24, plate XVI.—It consists of two concentric vessels, made of japanned tin.

The substance to be congealed is put into the interior vessel *a*, surrounded with a freezing mixture, whilst the outer vessel *b*, is filled with powdered ice, and muriate of ammoniac, or any other mixture capable of producing a great reduction of temperature; fig. 25, shows the cover of the vessel, which is also filled with the freezing materials.

FREEZING APPARATUS, (Dr. HENRY'S), fig. 60, plate I.—This is a convenient apparatus for freezing mercury in the small way, and at a cheap rate. The outer vessel of this apparatus is constructed of wood, furnished with a wooden cover, rabbetted in and furnished with a handle. Within this is contained a vessel made of japanned tin *b b*, on which rests a shallow tin pan *c c*. Within this second vessel *b b* is a third, marked *d*, made of untinned iron. When the apparatus is to be used, a freezing mixture, composed of muriate of lime and snow, or pounded ice, is put into the outer vessel *a a*, so as completely to surround the middle vessel *b b*. Into the latter the vessel *d*, containing the quicksilver to be frozen, previously cooled down by a freezing mixture, is put; and this is immediately surrounded by a mixture of snow, and muriate of lime previously cooled to 0° Fahrenheit, by a mixture of snow and muriate of lime. The pan *c c* is also filled with these materials, and the wooden cover is then put into its place. The apparatus is now left till the quicksilver is frozen, which is also filled with the freezing materials.

FREEZING APPARATUS, (Mr. PEPY'S), fig. 14, plate IV.—This is an elegant contrivance for experiments on artificial cold; well adapted for public exhibition. It consists of an exterior and interior oval vessel of japanned iron. The interior vessel *a a* being one inch less in every

direction than the outer one *bb*; *cc*, are detached circular vessels, placed in the interior one, for containing the freezing mixtures. This apparatus is very convenient for exhibiting the freezing of quicksilver during the heat of summer. The freezing mixture employed may consist of sulphate of soda and diluted sulphuric acid: but when ice can be procured it should be preferred, and used in the pulverized state with muriate of lime. When the apparatus is to be used with sulphate of soda and diluted sulphuric acid, it is advisable to dilute the acid the preceding day, in order that it may be of the same temperature as the surrounding air, when the experiment is to be performed.

This being done, let two phials of about four ounces capacity of water be filled with diluted sulphuric acid, place them in the middle of the cylindrical vessels *cc*, and surround them with pulverized crystals of sulphate of soda, so as to fill the vessels *cc* completely; and cool down the whole by placing it into the interior vessel *aa* of the apparatus, by surrounding it with a freezing mixture, consisting of sulphate of soda and diluted sulphuric acid. The cover of the apparatus (which is exhibited in the drawing) is to be put on, and when the latter is likewise filled with the same freezing mixture, the whole is suffered to stand for about 25 or 30 minutes. The cover is then taken off, and the cylinders *cc*, containing the sulphate of soda and diluted acid, are then emptied as expeditiously as possible into the large cylinder *d*, containing the mercury included in a glass tube or phial.

FUEL.—See **HEAT AND FUEL**, page 6.

FUNNEL, fig. 7, plate XVI.—The common funnel requires no description. The chemical laboratory should

be provided with funnels of glass, brown stone ware, porcelain, and tinned iron, of different æreas,

FUNNEL FOR SEPARATING DELIQUESCENT SALTS, fig. 4, plate XI.—*a* denotes a small circular stand, holding a funnel which has a very shallow ærea, and a narrow tube *c*, terminating in a small bottle *d*, to collect the deliquescent salt, which has been occasioned by exposing the saline mass over the ærea of the funnel, in the atmosphere. Fig. 6, plate XV., shows another modification of the same funnel.

FUNNEL, HYDROSTATIC, fig. 4, plate I.—The use of this funnel is to pour fluids into retorts or other vessels in which an operation is going on, without admitting external air, or deranging any part of the apparatus. It is evident that any portion of fluid poured into the funnel *a*, more than sufficient to fill the two first parts of the bent tube, up to the level *z*, will escape by the lower extremity *b*; at the same time no gas can return through this funnel, unless its pressure be able to overcome the resistance of a column of fluid of the height of the leg of the funnel marked *y, z, a*.

Fig. 61, plate I, shows the adaptation of the funnel to a retort, fig. 5.—See also *e, d, f*, of fig. 8, plate III., fig. 9, plate IV., or *a, b*, fig. 12, plate XII.: plate I, is another contrivance for the same purpose. It consists of a common funnel, in the throat of which is inserted a rod with a conical point, which regulates the passage of the fluid through the funnel, according to the firmness with which it is inserted.—See also *x*, fig. 9, plate IX. or *x*, fig. 51, plate I.

FUNNEL, (RETORT FUNNEL), fig. 5, plate I.—By means of this horizontal funnel, fluids may be introduced

into the body of a retort, to prevent the neck from becoming soiled.

FUNNEL, SEPARATORY.—This name is given to the apparatus exhibited fig. 20, plate IV. It is always made of glass, and serves for separating liquids of different specific gravities, for instance, oil and water, by allowing the heaviest only to drop out of the bottom of the vessel; the stop-cock *a* at the bottom being closed, and the vessel then filled with the mixed liquors. When they have stood at rest till the heaviest has entirely subsided into the narrow part below, the stop-cock at bottom is opened, and when the stopper *b* at the top is loosened the heavier liquor flows out. This vessel is used particularly for separating essential oils from the water which is necessarily entangled with them when collected from the water distilled from plants that yield them. Some of these are lighter than water, others heavier, and they are both separated with equal ease. Fig. 10, plate IX., is the same contrivance without a stop-cock.

FURNACE, CHEMICAL.—The utmost degree of heat that can readily be produced by a common parlour stove supplied with coals, is barely sufficient to melt a thin silver coin, for example a shilling. But a very large number of the operations in chemistry are performed in a temperature not exceeding a full redness, and for many of these the common grate is amply sufficient. The flat iron sides or cheeks will also furnish an inferior heat, on which evaporating and digesting vessels may be set. The common grate however has two disadvantages, one, that the openness of the front causes the escape of a great part of heat, and incommodes the chemist in approaching it, and the other, that coal is a very unsteady

variable fuel, giving much blaze and smoke, and requiring frequent stirring.

Before we describe the proper chemical furnaces, we may shortly state what must be their object and construction.

The best construction of a furnace has not been well ascertained from experience. There are facts which show, that a fire made on a grate near the bottom of a chimney, of equal width throughout, and open both above and below, will produce a more intense heat than any other furnace. What may be the limits for the height of the chimney is not ascertained from any precise trials; but thirty times its diameter would not probably be too high. It seems to be an advantage to contract the diameter of a chimney, so as to make it smaller than that of the fireplace, when no other air is to go up the chimney than what has passed through the fire; and there is no prospect of advantage to be derived from widening it.

In general, however, the flue of the chimney is made a little narrower than the ash-pit. A close furnace of this kind, intended simply for heating any vessel in the midst of the fuel, requires essentially no more than three openings, namely, the ash-hole, the chimney, and a side-door, through which to throw the fuel, and to introduce and take out the substance to be heated.

Where distillation by naked fire is wanted, a small addition is required, and a hole must be cut level with the middle of the retort, through which its beak may emerge, and connect with the receiver or other vessel intended to collect the product. The retort in this case is generally of earthenware.

Another object in furnaces is to apply a moderate degree of heat to larger vessels, which therefore can only be partially in contact with the fire. Most of the furnaces used

in manufactures and for many common purposes are of this kind, such as the common household coppers for heating water, brewing coppers, salt-pans, &c. &c. Sand pots are also of this kind, and in all these, the substance to be heated is placed over the fire, sometimes dipping into it. This also essentially requires only three openings, viz. the ash-pit, chimney, and door for fuel, the surface of the substance heated being external to the fire.

Another purpose in furnaces is to inclose and heat on all sides an earthen oven or muffle, the mouth of which at the same time comes in contact with one of the inner sides of the furnace, and is freely accessible from without by a corresponding hole cut through the substance of the furnace. This, therefore, requires another opening besides the three former already mentioned.

It is sometimes required in experiments of research to place an earthen or iron tube in such a manner, that the middle of it shall be strongly heated whilst each end is cool, and projecting beyond the furnace, so that no part of the contents of the tube can come in contact with the fuel. This is done in a close furnace, by having two holes through the sides directly opposite each other, through which the tube may be thrust.

One more mode of distributing the heat of a furnace may be mentioned, which is, where the substance to be heated is neither to be inclosed in any vessel, nor in actual contact with the fuel, but is spread on a kind of floor immediately beyond the fire, in a space between the fireplace and the chimney, and receives the heat from the flame which draws over it. This forms the reverberatory furnace, and requires a very peculiar construction.—*See REVERBERATORY FURNACE.*

The above are the principal objects to be fulfilled in the construction of chemical furnaces for general purposes,

but another great distinction is in the mode of supplying air, which may be either by the natural draught of air, or by bellows, or other artificial means. In the former case the rapidity of the current of air and consequent intensity of the fire, depends on having a sufficient space in the ash-pit and chimney, and especially a very great length of flue, and all the side-openings which would break the current, carefully closed. But with an artificial blast the strength of fire depends solely on the degree of mechanical power employed in impelling the blast, and the chimney is altogether superfluous except to carry off the smoke. These kind of furnaces, therefore, are much simpler than the draught furnaces, as no more is required than a simple hearth or a shallow pot, with a small hole at the bottom to conduct the air from the bellows. Large quantities of materials, as in the smelting of iron, can hardly be heated to the utmost intensity without the artificial blast, and the assistance of a blowing engine or some other strong mechanical force, is necessary to keep up the constant supply of air. At least, much time and fuel are saved by the blast, for if the heat of the most powerful draught-furnaces, such as the porcelain kilns, may be brought to equal that of the iron-smelting furnace, it requires, however, a very large body of fuel and a great many hours to bring it to the intensity. But in the small way, for experimental purposes, the highest temperature of the draught-furnace, when well built and properly attended to, appears to be no way inferior to the best blast, to judge by the comparative effects; and the greater consumption of fuel and time is often fully counterbalanced by the saving of manual labour.

Some chemists have supposed that the heat of a furnace might be reflected from the sides, and concentrated into one focus, by giving it a circular or elliptical form.

This, however, is found by experience to be perfectly nugatory, for no sensible difference is observed between a cylindrical, globular, or elliptical fire-place, provided the dimensions of the chimney and ash-pit are the same. There is, however, a method of concentrating the heat of a blast-furnace, by dividing the blast into a number of smaller jets of air, and mechanically driving them towards a common centre.

The materials of which furnaces are constructed is always a refractory clay, either in form of bricks, or, where the pieces of the furnace are small, of entire pottery. The larger kinds of black-lead crucibles make extremely useful portable furnaces for a variety of purposes, being very infusible, bearing pretty sudden heating without splitting, and having the additional advantage of being so soft as to be readily drilled by a gimblet, and cut by a saw or hacked knife, whereby openings may be made and stoppers fitted without difficulty. Large moveable furnaces are often made of this kind of pottery, but much thicker than the common crucibles, and strengthened on the outside by iron hoops. A very useful white coarse pottery is employed in France for portable furnaces, which bears the fire extremely well, but when baked is too hard to be cut like our black lead ware. Moveable furnaces are often made of a wrought-iron case lined on the inside with small fire-bricks, and the part immediately in contact with the fuel is further covered with a thick coating of Windsor loam, laid on when moist and plastic, and beat frequently with a wooden instrument when drying, to give it more compactness, and to fill up the small cracks which the shrinkage occasions. The fixed furnaces are always built of *fire-bricks* (a very hard infusible brick, made for this express purpose) cemented with a very refractory mortar ; and the larger openings are either

iron doors set upon hinges, or sometimes a thick piece of free-stone, or a very large brick properly fashioned. There is a very soft red sandy brick sold in London, under the name of *Windsor brick*, which may be cut or scraped with great ease, and is extremely useful for stoppers, crucible stands, and many other smaller purposes, though it is too soft to bear any considerable pressure.

FURNACE, AIR FURNACE, (KNIGHT's).—See page 29.

FURNACE, AIR FURNACE, (CHEVIX's), page 30.

FURNACE, ASSAY FURNACE, page 40.

FURNACE, REVERBERATORY.—Figs. 2, 3, and plate XV.—Are the section and plans of a reverberatory furnace for experimental purposes. In this furnace, the fuel is contained in an anterior fire-place; and the substance, to be submitted to the action of heat, is placed on the floor of another chamber, situated between the front one and the chimney. The flame of the fuel passes into the second compartment; by the form of which it is concentrated upon the substance exposed to heat, which is not confined in a separate vessel or crucible, but placed on the floor of the furnace. When reduced to a state of fusion, the melted mass is allowed to flow out through a tap-hole at *h*. The dimensions of this furnace it is scarcely possible to state, as they vary so considerably in different parts of it; but they may be ascertained by referring to the figures, and by the application of the scale. In all three figures, *a* represents the ash-pit; *b* the grate composed of moveable bars; *c* the door at which the fuel is introduced; *d* a door in the side

of the chamber, for the purpose of inspecting the process ; *e* the floor of the furnace which descends, and is gradually contracted towards the back part ; *f* another door for introducing and stirring the material ; *g* the back part of the furnace, immediately under the chimney ; *h* the tap-hole ; *i* the chimney. Fig. 4, and 5, exhibits the shape of fire bars best adapted for furnaces.

FURNACE, PORTABLE TABLE FURNACE, (KNIGHT'S), figs. 6 and 7, plate XV.—This furnace is composed of strong iron plates lined with fire lute, the inside diameter is six inches ; *x* shows the grate ; *b* the ashpit door ; *d* the door of the fire-place when used as a sand heat ; *e e* two holes opposite to each other for transmitting a tube ; *g* an opening for the retort neck, when used for distilling with the naked fire.

Fig. 7, A different view of the same furnace ; *x*, the grate ; *c* the register to the ash-pit. The other letters correspond with the explanation of the preceding figure.

For this furnace the proper fuel, when it is used as a wind-furnace, is wood-charcoal, either alone, or with the admixture of a small proportion of coke. For distillation with a sand heat, charcoal, with a little pit coal, may be employed.

FURNACE, BLACK LEAD TABLE FURNACE, fig. 11, plate X.—These furnaces, which are made of two large black lead crucibles, *a a*, applied mouth to mouth, and strengthened with iron hoops, *b b*, are not capable of producing a strong heat, but may be employed for many ordinary purposes. Their size enables them to be used on the table, and to move them to any place where wanted. The fuel to be burnt in these furnaces is charcoal ; they

are brittle, and consequently liable to accidents, particularly when hot: *x* is the sheet iron chimney.

FURNACE, FIXED UNIVERSAL, Figs. 1, and 14, plate XV.—The inside of this furnace is nine inches square, and sixteen inches deep from the top to the grate. The face of the opening rises at an angle, which makes the back part five inches higher than the front. This contrivance enables us completely to cover a large retort with fuel, without obstructing the passage of the air, and also relieves partly the weight of the cover, when it requires to be moved. The walls of the furnace are at least a brick and a half in thickness, and as much more as local convenience will allow. By sinking the ash-pit below the level of the ground, the height of the furnace need not exceed eighteen inches, which renders the management of the fuel much more easy, and subjects the face and hands less to the action of the heat. The ash-pit *a*, must be at least eighteen inches deep, below the surface of the ground, and more if convenient. It must have an opening, projecting from it three or four feet, to be covered with boards, and with an iron grating next the furnace. This preserves the legs of the operator from the action of the fire.

The grate *b* is formed of separate bars, each of a triangular shape, three fourths of an inch apart, and resting on two bearers. In the front of the furnace, an iron bar is to be placed to support the brick-work, and to leave an opening, through which the bars may occasionally be drawn out, and the fire be raked and cleared of the slag. The chimney *e* is two and a half inches from the top, and four and a half wide, by two and a half high.

To fit this furnace for occasional distillation with the

naked fire, an opening, *d*, is left on one side, which is filled up, when not wanted, by five pieces of soft fire-brick, cut to a proper shape, and secured by a clay lute. It is proper, also, to be provided with other pieces, having arched openings for transmitting the neck of a retort. One of these pieces may have a round hole for occasionally transmitting a tube, and a corresponding hole must then be made in the opposite side of the furnace, to be closed, when not wanted, with a stopper.

FURNACE, (Dr. HENRY'S) WIND FURNACE, fig. 8, plate XV.—This furnace may be used either as a wind-furnace, or for distillation with a sand heat. Its total height outside is thirty-three inches, and the outside square is eighteen inches, or two bricks laid lengthwise. The thickness of the sides of the furnace is the breadth of a brick, or four and a half inches; but whenever there is room, it is better to make them nine inches in thickness. From the top of the furnace to the grate, which is moveable, and supported by two bearers, the height is thirteen inches. It has a double Rumford door: or in preference, a hole closed by a moveable earthen stopper, for introducing fuel. The ash-pit should have a register door. The chimney is four inches wide by three high, and may either be furnished with a damper or not. On the top of the furnace a cast-iron ring is fixed, ten inches inside diameter, three inches broad, and half an inch thick. It is secured in its place by three iron pins, passing through three equidistant holes in the ring, and bent at the distance of nine inches at a right angle. These serve the purpose of binding the ring firmly into the brick-work. The sand pots are of different sizes; and a variety of them may be made to fit the same ring, by varying the breadth of their rims. The bricks should be

cemented together, at least for the inner half of their breadth by loam, or by a mixture of Stourbridge clay, with two or three parts sand, and a proper quantity of water.

When this is used as a wind-furnace, the opening in the side is to be closed by its stopper; or, if a Rumford door be employed, it must be defended from the fuel by a fire tile. The fuel (coke) is introduced at the top, which is occasionally covered by a fire tile. When distillation with a sand heat is performed, the sand pot rests on the iron ring, and the fuel, which may be common pit coal, is added through the opening in the side. It may be proper to state, that in order to receive a sand pot of as large a size as possible, the upper course of brick should be bevelled within the furnace, and the width at the top may exceed a little that at the grate.

The best Stourbridge or Newcastle-on-Tyne fire bricks are necessary in constructing this and all other fixed furnaces.

FURNACE, (BARUEL'S), for making gaseous oxyd of carbon, fig. 1, plate III.—The object proposed in this arrangement is to oblige the gas evolved from carbonate of lime to traverse charcoal contained in three gun-barrels, *b, c, d*, and thus to saturate itself with all the carbon it can dissolve. It may likewise be used for procuring sulphuretted hydrogen, carburetted hydrogen, phosphoretted hydrogen, and for saturating gases with any gaseous substance, when a high temperature is requisite for that purpose. The apparatus, however, is too complex, too expensive, and too easily put out of order, to deserve general adoption. Fig. 2, shows a horizontal section of the furnace; *a a a* are the gun-barrels; in fig. 9 *b* is a pneumatic cistern, and *c* the bottle from which gas proceeds into the barrels.

FURNACE, (KNIGHT'S,) WIND-FURNACE.—See **AIR FURNACE**, p. 29.

FURNACE, (AIKIN'S), See **BLAST FURNACE**, page 54.

FURNACE, UNIVERSAL PORTABLE, fig. 1, plate XV. and geometrical view of the same furnace, fig. 14, plate II.—Among the whole group of apparatus designed for applying heat to bodies, this furnace undoubtedly is for the purposes of experimental chemistry the most useful, however numerous and different the operations to be performed may be. It may be used with perfect safety in a room, and is, therefore, well calculated for those operators who have no access to the laboratory, as well as for public lecturers on chemistry. A very large number of chemical processes may be carried on in this furnace commodiously and at a cheap rate.

For the *smelting of metallic ores*, or for operating with the crucible, the vessel with its stand or support is placed on the grate, in the midst of the fire, the larger opening, which in the design is occupied by a sand pot, *a*, in which a retort is placed, (or mouth of the furnace), is closed with its cover, and the fuel introduced at the top, or through one of the openings in front *cc*.

When *distillation by the naked fire* is to be performed with this furnace, the retort is placed in the fire, on a crucible stand, and the beak of it is made to pass through one of the front openings *c, c*. The same proceeding serves to obtain such gases as cannot be disengaged without exposing the materials that afford them to a red heat, viz. oxygen from oxyd of manganese, gaseous oxyd of carbon, &c.

For *distillation, or sublimation from the glass retort*,

or the alembic, an iron sand-pot, fig. 23, plate XVI. or fig. 32, plate I. is put in its place as shewn in the design; the fuel then is added through one of the front openings, *c, c.* In this sand-bath may likewise be placed flasks, digesters, matrasses, evaporatories, and other vessels, to receive an uniform, safe, and gradual heat.

For *evaporation by the water bath*, a shallow pan, (figs. 10 and 16, plate XVI.) filled with water, and placed on the mouth of the furnace, may be employed.

For *roasting metallic ores*, and other minerals, to free them from sulphur, arsenic, &c. a muffle, fig. 16, plate I. should be placed, or better luted with clay, in the lower front opening; the fuel is then introduced at the top or mouth. To *assay gold or silver, and to enamel or paint on glass*, the same arrangement is convenient.

The *decomposition of water*, by passing steam over ignited iron or charcoal, may be performed by laying an earthenware tube, *x*, fig. 14, plate II. or gun barrel through the side openings, as shewn in the design. The middle part of the barrel may thus be made red hot, whilst each extremity is readily kept cool, and may be connected with any kind of apparatus.

For *evaporating by the naked fire*, the iron rings 1, 2, shown near fig. 22, plate XVI. which are of different sizes, serve to lessen the upper opening of the furnace on which they are put, so as to adapt it to the size of the evaporatory vessel, whatever its diameter may be. The largest ring is first placed on the mouth of the furnace, the second in size is put on the first, &c. until the opening is sufficiently lessened.

The different apertures which are in the front and sides of this furnace are provided with solid stoppers of crucible ware, fitted by grinding, to close the apertures,

consequently, whenever one or the other is not employed, they are further covered with iron doors, to keep out the air effectually.

The register doors at the ash-pit, serve as dampers to regulate the heat with precision, by admitting or excluding air at pleasure, when more or less opened or shut. To increase the draught of the fire on particular occasions, an iron pipe, eight, ten, or twelve feet long, and not less than four or five inches in diameter, may be added to the short chimney, *h*, which can be adapted to any fire-place; by this means the draught is augmented prodigiously. It is not essential that this pipe should be extended perpendicularly; on the contrary, it may be placed horizontally, oblique, or proceed in any direction as local conveniences will allow: the waste heat produced by this pipe may be employed to warm the laboratory, or for other purposes. And as this furnace is very heavy, being made of strong hammered sheet iron and lined with fire bricks within, it is placed upon castors, and strong ring handles are affixed to its sides, that it may be moved along the floor without much trouble.

The fuel to be used, if an intense heat be wanted, should be coke and charcoal mixed in about equal quantities, and broken into pieces of the size of an egg; for ordinary purposes common coal answers very well. The height of this furnace from the grate to the top, is fifteen inches; the cross diameter within ten; the height of the ash-pit to the grate is seven inches; the front openings, *c*, *c*, measure four inches by three and a quarter. The fire-bricks with which the body of the furnace is lined, are wedge-shaped, and cemented together by fire lute, to render them not liable to become injured by accidental blows, &c.; they are, moreover, interlaced with slips of sheet iron, bent twice at right angles, to clamp them

together, and to bind the whole lining to the outer case of the furnace. The interval between the brick work and the outer coat of the furnace, which is two inches and a half thick, is filled with charcoal powder and loam, which mixture confines the heat effectually.

FURNACE, CHEMICAL LAMP FURNACE, fig. 6, plate VII., or fig. 16, plate II.—The lamp-furnace, as it is perhaps not very properly called, is one of the most convenient means of applying the brilliant flame of an Argand's lamp to the purposes of experimental chemistry. A vast number of chemical operations may be performed with great speed, precision, and perspicuity, by means of it. Indeed the lamp-furnace may be used for almost every one of the operations of chemistry in the small way, which require a temperature not exceeding a *dull red heat*. The process of digestion, the sublimation of salts, the solution of earthly and metallic bodies, the concentration of liquids, all the multifarious processes of distillations by the sand-bath, and by naked fire, the production of gases with the pneumatic apparatus, and even the fusion of earthy minerals with alcalies for analysis, may commodiously be accomplished, at a trifling expense, on the table, with the help of this instrument. Besides the heat produced by the lamp-furnace has the capital advantage of being easily regulated: it may at pleasure be suppressed instantly, or maintained for several hours at a constant and determinate intensity. These advantages alone will be valued properly by those who know that the most experienced and most attentive chemists meet in practice with frequent accidents, by which both the vessels and the products of the operations are lost for want of power in the proper management of the fire. It is thus also that a number of minute circumstances, which are essential to

be known to the student, pass away unnoticed among the furnaces of the regular laboratory, which may be observed when the same process is conducted on the table, and under the immediate eye of the experimenter. Fig. 16, plate II. exhibits a lamp-furnace in action, connected with an apparatus, to shew the formation of a gas. Fig. 9, plate IV. exhibits a lamp-furnace, it consists of a brass rod, *a*, fixed into a solid brass foot loaded with lead *b*; on this rod slide three metallic sockets with straight arms, to which are screwed brass rings of different diameters, *c c c*, for supporting a glass basin *d*, or a flask *e*, and each of these rings may, by means of a milled head and screw *fff*, be set at different heights. Below these rings is placed a spirit lamp *g*, supported on a wooden sliding stand, (fig. 11,) which may be elevated or depressed in order to cause the lamp to communicate more or less heat to the vessel suspended over it.

FURNACE, LAMP FURNACE, WITH CONCENTRIC WICKS, fig. 6, plate VII.—In this lamp-furnace a second cylindrical wick is added to the common Argand's lamp of the apparatus. These two wicks being concentric, and each of them having an interior and exterior current of air, a double flame is caused, and the power of producing heat is augmented to more than three times that afforded by the ordinary lamp of Argand; a circumstance which renders the use of this apparatus in the small way, almost equal in effect to a sand-bath. The oil to be burnt in this lamp should be of the very best kind.

Fig. 9, plate VII. shews a perspective view of the wick-holder of the lamp, and fig. 7, plate VII., is a perpendicular section of it.

FURNACE, LAMP FURNACE, (GUITONS'), fig. 13, plate

IV.—A, is the body or reservoir of the usual Argand Lamp, with a shade and glass chimney; *b* a thumb screw for raising the lamp, *d* a support, consisting of a round stem of brass formed of two pieces, which screw together at about $\frac{2}{3}$ of its height. Upon the circular ring *e*, the arm *f* and the nut *g* slide, and are moveable by its respective thumb screw. The arm also carries a moveable piece *h*, which serves to suspend the vessels in a convenient situation, or to secure their position. The whole support is attached to the square iron stem of the lamp by a piece of hard wood *i*, which may be fixed at any required situation by its screw; *k* represents a stand for the receivers. Its moveable tablet *l*, is fixed at any required elevation by the wooden screw *m*. The piece which forms the foot of this stand is fixed on the board *n*; but its relative position with regard to the lamp may be changed by sliding the foot of the latter between the pieces *oo*; *p*, another stand for the pneumatic trough. It is raised or lowered, and fixed to its place, by a strong wooden screw, *q*; *r* is the tube of safety, or reversed syphon, invented by Welter, (see Tube of Safety). The arrangement of this lamp furnace is complex, which renders it expensive and cumbersome.

GASOMETER.—The extended application of the gasometer in the practice of chemistry is sufficiently known. One of the most simple gasometers, and which answers sufficiently, for all common experiments, is that represented in fig. 18, plate XI. It is made of tinned iron, the surfaces of which are japanned. It consists of two principal parts; a large vessel *a*, somewhat bell-shaped, which is designed to contain the gas, and a cylindrical vessel of rather greater depth, *b*, in which the former is placed, and which is designed to contain the water by which the gas is confined. To diminish, how-

ever, the quantity of water, this cylindrical vessel has a cone within it, also of japanned tinned iron, adapted to the shape of the gas-holder, so that this latter slides between this and the cylindrical vessel, and a small quantity of water is sufficient to fill up the space between them. The vessel designed to contain the gas, is suspended by cords hung over pulleys, to which weights are attached, so as to counterpoise it. From a stop-cock *d*, at the under part of the apparatus runs a tube under the cylinder, which rises through the centre, passing through the cone, the opening by which it passes being soldered so as to be air-tight, and terminating by an open mouth at the upper part of the bell-shaped vessel *a*. This tube, at the part where it is bent at right angles, to ascend as has been described, is connected with another tube which also runs under the bottom, and ascends on the outside, terminating in the stop-cock *e*, so that from one stop-cock to the other, through the gas-holder, there is an uninterrupted passage. When the instrument is to be used, the stop-cock *d* is opened, and the vessel *a* pressed down, a sufficient quantity of water being in the outer cylinder; the air of the vessel is forced out by the pressure, and its place is occupied by the water in which it is thus immersed. When this is effected, the stop-cock is closed, and now, if we wish to introduce any gas into the apparatus, a bent funnel, the mouth of which is placed in a vessel of water, is attached to the tube of the stop-cock *d*, and the stop-cock is opened. If the extremity of a retort, or of a tube conveying gas, terminate below the orifice of the funnel, the gas will rise along the tube, will ascend to the top of the gas-holder, and this being counterpoised, will, as the gas enters, rise in the water until it is filled, a quantity of water, of course, remaining around the mouth of it, by which the gas is confined. When we wish

to expel the gas, the stop-cock *d* is closed, that at *e* is opened, a flexible tube *f* is adapted to it, and the bell being pressed down, either by the hand, or by its own weight from the removal of the counterpoising weights, a stream of gas issues from the extremity of the flexible tube, and may be transferred into a jar, or applied to any other purpose, and its quantity may be measured by the instrument being graduated by a scale marked on the rod *f*. Besides the ordinary purposes to which it is applied, namely, to enable the chemist to collect and to preserve large quantities of gases, this machine may be used as an excellent blowpipe, to keep up for a long time an uninterrupted blast of air; the velocity of the stream may be increased or diminished at pleasure, by the pressure which the operator applies to the bell *b*, of the machine. In substituting oxygen gas for common air in the gasometer, an opportunity is given to excite the most intense heat that combustion can produce. For breathing gases, the gasometer is the most convenient instrument.

The gasometer exhibited fig. 9, plate XI. being represented as transparent, shows the construction of the apparatus more distinctly. It differs in nothing from the former, except in the arrangement of the pulleys; fig. 6, plate V. shows the gasometer connected with two gas-holders.

GASOMETER, MERCUREAL, (PEPYS'S,) fig. 12, plate XI.—For experiments on gases, which require much accuracy, and which cannot be performed over water, this gasometer, which is made of cast iron, is extremely useful. The experiments may be performed by means of it, on a tolerable large scale, although the necessary quantity of mercury to fill the gasometer, &c. is compa-

ratively small. The apparatus, however, is too costly and too easily put out of order to be accepted with welcome among the generality of the cultivators of chemical science.

A, is a representation of the bell of the gasometer, made of glass, furnished with a cock at top, and able to contain 34 ounces troy of distilled water. The divisions of capacity, determined by actual measurement, are marked on the glass with a diamond. *B B*, section of two cylinders of cast iron, the outward one screwed upon the solid internal one, which is made to project at its lower extremity, and furnished with a male screw, to work into a female screw with which the lower end of the external cylinder is furnished. The space between these is so adjusted as to be almost filled up by the substance of the glass bell *a* when dropped into it, so that the quantity of mercury necessary to fill up that space is proportionally small. The internal cylinder has a conducting tube up through its axis, the lower end of which is furnished with a female screw answering to the male screw of the cock of the small receiver *c*. The receiver *c* is made of glass, and open at bottom. When this receiver is used, it is screwed into its place, and rests upon a small cup or cistern of mercury *d*, in which the beak of a retort, furnished with a bent glass tube, to be afterwards noticed, may be introduced under the receiver. *E, e, e, e*, section of a wooden stand upon which the cast iron cylinders are supported, having an opening through the top to permit the cock of the receiver *c* to be joined to the conducting tube of the internal cylinder *b*. The cistern *d* is adjusted to its height by means of a rising cylinder in the pedestal *f*. *a*, fig. 2, a glass globe and stop-cock, for weighing gases: it receives its gas by being inverted, and screwed into the bell glass *e*. Fig. 15, is a bladder furnished with a

stop-cock to assist in holding, transferring, or mixing different gases; fig. 11, is an elastic gum-bottle, capable of containing 30 ounces of distilled water, for holding acid gases: when used, it is screwed into the top of the receiver *e*, fig. 2; the bottom cock of the thin transfer, *x*, being at the same time joined to the bell *e*, previously charged with the alkaline gas: the cocks being turned, the gases rush together in vacuo. Fig. 13, a small portable exhausting air-pump, for exhausting the globe *a*. *d*, a double female screw, which fits any part of the apparatus, and on which a valve may be fastened.

One of the principal objections to the use of mercury in such experiments as this apparatus is intended for, has been, the great force necessary to overcome the resistance of a column of mercury when gases are to be received over that dense fluid; a resistance in the proportion of one inch of mercury to fourteen inches of water, and which very few lutes are able to withstand. This resistance is here overcome by a very simple contrivance: a bent tube fitted into the beak of the retort *x*, (if one be employed), or into a Wolf's apparatus, and passing into the upper part of the small receiver, as expressed in the plate at *c*. By employing mercury for such experiments, another advantage is gained by the use of this apparatus, namely, a power of exhaustion in the retort, or Wolf's bottle, equal to a column of two inches of mercury, or 28 inches of water. This will be easily conceived when it is recollected that, by drawing up the large receiver *a*, the small one *c* is raised in its cistern, bearing up with it the contained mercury, which is kept in its place by the pressure of the atmosphere on the surface of the mercury in the cistern. The cock of the small receiver is then to be turned off, and that of the large one to be turned on. The air, of which the retort, or wolf's bottle, is thus exhausted, may

then be let out, by plunging the small receiver into the mercury between the cylinders, and turning off the cock. When a sufficient quantity of gas passes from the retort, or bottle through the bent tube to level the mercury in it, and the cistern, the communication may again be opened, and the same steps followed as before described. By this means we are enabled to obtain more gas from the same materials, than if we had received it through a fluid of the weight of water; a circumstance of some importance where nice and accurate results are looked for.

The plate of the apparatus is on a scale of nearly three inches to a foot.

Fig. 1, plate XI., is an elastic gum bottle, adapted to fit the stop-cock, at the top of the bell of the gasometer.

GASOMETER, MERCUREAL, (CLAYFIELD). Fig. 8, plate V. fig. 2, plate V. represents a section of this machine, which consists of a strong glass cylinder *a*, cemented to one of the same kind *b*, fitted to the solid block *c*, into which the glass tube *d* is cemented for conveying air into the moveable receiver *e*.

The brass axis having a double bearing at *a*, *a*, is terminated at one end by the wheel *g*, the circumference of which is equal to the depth of the receiver, so that it may be drawn to the surface of the mercury by the cord *b* in one revolution: to the other end is fitted the wheel *h*, over which the balance cord *e* runs in an opposite direction in the spiral groove *e*; a front view of the wheel *h* is shewn at fig. 11.

Having loaded the receiver with the weight *i*, something heavier than may be necessary to force it through the mercury, it is balanced by the small weight *k*, which hangs from that part of the spiral where the radius is

equal to that of the wheel g , from this point the radius of the spiral must be increased in such proportion, that in every part of its circuit, the weight k may be an exact counterpoise to the air-holder. In this way, so little friction will be produced, that merely plunging the lower orifice of the tube d under mercury contained in the small vessel l , will be sufficient to overcome every resistance, and to force the gas discharged from the beak of a retort into the receiver, where whatever may be its quantity, it will be subjected to a pressure exactly corresponding to that of the atmosphere. The edge of the wheel h being graduated, the balance cord c may be made to indicate its volume.

Should it at any time be necessary to reduce the pressure to the medium standard of the barometer, it may easily be done by graduating the lower end of the tube d , and adding to the weights i or k , as may be found necessary; the surface of the mercury in the tube pointing out the increase or diminution.

The concavity at the top of the internal cylinder is intended to contain any liquid it may be thought proper to expose to the action of the gas.

The upper orifice f , with its ground-stopper, is particularly useful in conveying air from the retort g , with its curved neck, into the receiver, without its passing through the tube d . In all cases where a rapid extrication of gas is expected, the retort g , should be firmly luted to the orifice, and the weight i , removed from the top of the receiver, this by diminishing the pressure, will admit the gas to expand freely in the air-holder at the instant of its formation, and prevents an explosion of the vessels. The same caution must be observed whenever any inflammation of gas is produced by the electric spark.

The air may be readily transferred through water or even mercury by the tube *h*.

To prevent an absorption of mercury in case of a condensation taking place in the retort made use of for generating air, Sir H. Davy has applied the stop-cock *i*, to which the neck is firmly luted. This stop-cock is likewise of great service in saturating water with acid or alkaline gases, which may be effected by luting one end of the tube *k* to the stop-cock, and plunging the other into the fluid in the small vessel *l*, cemented at top, and terminating in the bent funnel *m*—the tube *h* having been previously removed, and the lower orifice of the tube *d* either sunk to a considerable depth in mercury, or closed with a ground stopper. The bend of the funnel *m*, may be accurately closed by the introduction of a few lines of mercury.

The application of the stop-cock *n*, has enabled Sir H. Davy to perform some experiments on respiration with considerable accuracy.

GAS BOTTLE, fig. 2, plate IX., and *b*, fig. 18, plate II.—When a gas is extricated, in consequence of chemical action, with the application only of a moderate heat, the glass flask or bottle with recurved tube is used. All these kind of bottles should be blown very thin at bottom, that they may support the heat of a spirit lamp suddenly applied, without cracking. In fig. 2, plate IX., the tube is fitted into the neck, by grinding; it is curved nearly in the form of the letter *s*. In the tubulated gas bottle, fig. 18, plate II., the body of the bottle is represented as containing a fluid in the act of combining with a substance that gives out air, which passes through the tube into the jar *a*, under whose mouth the other extremity of the tube is placed. For if a glass jar be filled with water, and placed inverted

on the shelf of the pneumatic trough, as shown in the design, the trough being filled with water to the edge, it is obvious that the mouth of the inverted jar being surrounded with water, the fluid within it will be sustained by the pressure of the atmosphere. If while thus filled, the extremity of the recurved tube connected with the bottle disengaging gas, be placed under it, or if another inverted jar, containing any air, be turned up, under the mouth of the bottle, advanced a little over the shelf, the elastic fluid, in either case, will rise through the water, displace it, and be collected in the jar; and while the mouth of this jar continues surrounded with water, the included air cannot escape, nor will the atmospheric air find access to it. In this way, then, aëriform fluids can be collected and preserved. Of these kinds of gas bottles, several will be required, of different sizes and shapes, adapted to different purposes, for a well furnished laboratory. If they cannot be procured, a Florence flask, with a cork perforated by a bent glass tube, or even by a tin pipe, will serve for obtaining some of the gases.—See fig. 17, plate II.; or, if the extrication of the gas requires no external heat, a common phial *a*, fig. 3, plate IX., furnished with a tube *b*, bent at right angles will do very well. If the gas be much heavier than common air, it may be collected without water, as shown fig. 51, plate I.

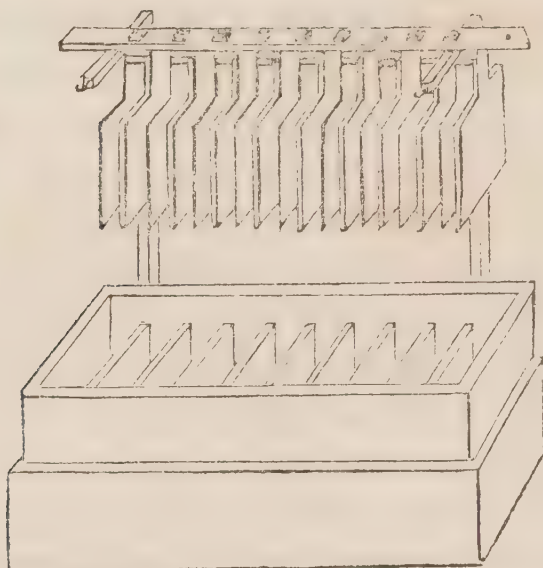
GAS APPARATUS, (Dr. URE's) for analysing gaseous bodies.—See **SYPHON FOR ANALYSING GASES**.

GAS HOLDER, (CAVALLO's).—See **AIR HOLDER**, page 32.

GAS HOLDER, (WATTS's).—See **AIR HOLDER**, page 31.

GALVANIC TROUGH, an invention of Mr. CRUICKSHANK.—It consists of a trough of wood, in the sides of which are cut grooves, at the distance from each other of from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch, according to the width of the box. Plates of two metals, usually copper and zinc, from three to six, or eight inches square, are soldered together, and this soldered or double plate is inserted in the first groove of the box, and fixed in it by a cement of resin and wax, so well applied that no liquid can pass through. This is repeated, fixing a double plate in each groove, and taking care that the order in which they are inserted shall not be reversed, but that the copper side shall always be towards the one hand, the zinc to the other. The space, therefore, between each pair of plates, forms a cell for the purpose of containing the liquid, by which the combination is to be made active. The advantage of this contrivance over the galvanic pile is, partly, that it is much more easily put in order; and, besides this, it is a more efficient instrument. When constructed in the way which has been described, it affords an example of a galvanic combination *of the first kind*, formed by two perfect and one imperfect conductors. But it admits of being modified, by cementing, into the grooves, plates of one metal only, and filling the cells, alternately, with two different liquids, as diluted nitric acid, and solution of sulphuret of potash. In this case, we have a battery *of the second order*, formed by the repetition of one perfect and two imperfect conductors. For the arrangement of other galvanic powers, the reader is referred to Donovan's Essay on Galvanism, and Singer on Electricity and Galvanism.

The following design represents another contrivance of a galvanic trough, with the plates out of the cells.

GALVANIC TROUGH, with moveable plates.

The zinc and copper plates, instead of being soldered together in pairs, as in the common galvanic trough, are here detached, and a communication between them is made at the upper edge, by means of a projecting piece, or metallic arc, from the centre of each plate. They are combined for the sake of convenience, in sets of twelve pairs, by means of a wooden rod. The trough is made of porcelain ware, divided into cells or partitions, corresponding to the number of pairs of plates in the trough. The plates, which are zinc and copper, may be introduced into this trough, so that one of the pairs of plates is at the one side of each partition, and the other at the other side; the connecting pieces, or arcs, projecting from the centre of each plate, forming the connecting arc, passing over each partition, and a plate of zinc, and one of copper, is thus placed in each cell. By this contrivance both surfaces of

the plates are acted on, and the whole series may be lifted out of the cells when not wanted for action, and supported upon two perpendicular iron rods, affixed to an outer wooden case of the trough, which is intended to protect the porcelain trough from accidents, as shown in the sketch.

GALVANIC BATTERY.—A number of galvanic troughs connected together have received the name of *batteries*; and these machines are said to belong to the first or second order, according as the simple combinations of which they are formed are composed of substances of the first or second order of conducting arrangements.

That end of the battery to which all the copper surfaces are turned, is called the copper extremity; that to which the zinc surfaces incline, is called the zinc extremity.

The fluids used for filling the trough, are either nitric or muriatic, or sulphuric acid, diluted with water or a mixture of these acids. No fluids except such as contain water can be employed in the Voltaic apparatus. Nitrous or muriatic acid, is, on the whole, preferable to any other; one part of nitrous acid, of the usual strength, being diluted with twenty or twenty-five parts of water. By this fluid, too, the surfaces of the plates are kept always clean, as it dissolves the oxyd formed. If muriatic acid, which is less expensive, be used, the proportion may be one part to sixteen or twenty of water. Muriatic acid is preferable to all other liquids; the nitric acid is more powerful in the same proportion, but its cost is four times as great, and it destroys the copper plates as well as the zinc. The nitrous gas evolved by its action is also much more unpleasant to the operator than hydrogen, which results from the employment of muriatic acid.

Mr. Children recommends a mixture of three parts fuming nitrous acid, and one of sulphuric acid, diluted with thirty parts of water.

In filling a galvanic trough with the fluid, it should be observed that it does not rise higher than about $\frac{1}{4}$ of an inch from the upper edge of the plates; and after the filling of the trough is completed, the upper edges of the plates, as well as the edges of the trough, should be carefully wiped dry, that there may be no communication between the fluid in the cells, but through the metallic substances. When the trough has been used with any of these fluids, it requires merely to be washed with water at the end of the experiment. The fluid may be bottled up, and reserved for future use; and if the most powerful action of the trough is not required, the same mixture may be employed several times. Here it may be worth while to notice, that the precaution of emptying the trough should be invariably observed, as soon as the experiments for which it was filled and prepared are finished; by this management there will be a considerable saving, both of the fluid and of the surface of the plates, which undergo oxydation. In combining together two or more troughs or batteries, to have the full effect of such a number of plates as may be employed, in proportion to the extent of their surfaces, the surface of the plates in each trough should be the same; otherwise, if troughs of different extent of surface be employed, the action of that trough which has the largest surface is diminished, and reduced to that of the action of the trough whose plates have the smallest extent of surface.

The plates of course must be opposed to the surface of a different plate; as, for instance, the zinc surface of one of the plates must be constantly opposite to the copper surface of the next plate in the series. The different

trough thus uniformly arranged, are to be connected together by means of metallic conductors. A slip of copper, for instance, about half the width of the trough, is inserted by its opposite extremities in the cells of the ends of two of the troughs.

To produce a shock by the galvanic trough, fill each interstice of the trough with the dilute acid, or selected solution for use, which is easiest done by elevating one end of the trough, and pouring the liquid into the first cell; the rest will successively fill of themselves, taking care not to fill the trough so that the tops of the plates will be covered with the liquid when laid down level. Then let the operator moisten both his hands with brine or water, and grasp a silver spoon or other piece of metal in each. If one extremity of the plates in the trough be then touched with one spoon, and the other extremity or the last plate in the trough with the other, a distinct shock will be felt at every repetition of the contacts. It is greater in proportion to the number of groups of plates of which the apparatus is composed.

GALVANIC CUPS.—Small cups, usually made of agate or flint, for showing the transfer of the elements of bodies in opposite directions through water, or porous bodies with which they have a strong affinity, without being retained. The annexed sketch exhibits the application of these cups.



Connect three cups, *h*, *g*, *f*, standing in a row, by a few filaments of asbestos, or wetted cotton, and pour a solu-

tion of sulphate of soda, or sulphate of potash, into the central cup *g*, and water tinged blue with tincture of cabbage in the two other cups, *h*, *f*, and connect the outer cups by means of the wires *d*, *e*, with the two ends of the galvanic battery; alkali will make its appearance in the glass negatively electrified, and the acid in the glass connected with the positive end of the battery, though neither of these glasses contained any salt, so that the acid and alkali must have been transported right and left from the cup placed in the middle, into the other glasses, by means of the connected fibres of moistened asbestos. The action of the alkali will become obvious by the blue tincture of cabbage acquiring a green colour, whilst the acid will change the colour of the tincture red. This experiment may be rendered more striking in the following manner.



Put into the central cup *k*, liquid ammonia, or a solution of potash, or soda, and in the glass connected with the negative end of the battery *l*, a solution of sulphate of potash or soda, and pour water into the positive glass *i*. The acid will be attracted by the positive wire, and appear in the glass *i*, after passing through the alkaline solution *k*, and without combining with it.

And, reversing this experiment, if an acid be substituted for the alkali in the central glass, and the solution of sulphate of potash be rendered positive, the alkali will be conveyed through the interposed acid, and go to the negative side of the battery.

In this manner, Sir H. Davy decomposed sulphate of

lime, sulphate of strontian, fluuate of lime, and other solid bodies, insoluble, or difficultly soluble, in water. In each case the earth was found in one vessel and the acid in the other. Even glass was decomposed, and part of its alkali exhibited entire. Sulphuric, muriatic, nitric, and phosphoric salts were decomposed with more rapidity; the acids in a certain time collected in the vessel containing the positive wire, and the alcalies and earths in that containing the negative; he connected a small cup made of sulphate of lime, with a cup of agate, by a piece of asbestos; and, filling both with purified water, a platina wire being inserted in the cup of sulphate of lime to transmit the electricity, and a wire in the agate cup for receiving it; in about an hour, a strong solution of lime was found in the agate cup, and sulphuric acid in the cup of sulphate of lime. By reversing the order, the sulphuric acid appeared in the agate cup, and the solution of lime on the opposite side.

GLOBE, DETONATING, *a*, fig. 2, plate XI.—A stout glass globe for detonating oxygen and hydrogen, and other inflammable gases; *d* is an ivory conducting piece, to insulate a metal conductor to convey the electric spark into the globe *a*. When the globe *a* is exhausted and connected with the receiver *e*, the gas contained in the latter of course will pass into the globe *a*, when a communication by means of the stop-cock *f* and *c* is established.

GRAVIMETER, fig. 10, plate VII.—The extensive use of the knowledge of specific gravities has produced a variety of contrivances, under the names of *Assay instrument*, *Hydrometer*, *Areometer*, *Gravimeter*, and *Pese-*

liquor, for the purpose of ascertaining the specific gravities of different bodies in an expeditious manner.

The construction of all those instruments depends upon the principle, that if a body whose specific gravity is less than that of certain fluids, be caused to float successively upon those fluids, it will sink deeper into the lighter than into the heavier fluid. Or that a greater addition of weight is required to keep the same part of the floating body below the surface of a heavier than of a lighter fluid.

The most simple gravimeter consists of a graduated rod or stem, *ca*, about 5 inches long, which is fixed to the bulb *a*. From the lowest part of *a* another stem proceeds a short way, and terminates in a smaller bulb *b*. The bulb *b* is partly or entirely filled with some metallic or other ponderous substance, which answers two purposes; it renders the instrument just heavy enough to sink as far as some part of the stem *ca* below the surface of the fluid which is to be tried by it; and it serves to keep the instrument upright in the fluid; hence it is placed as ballast in the lowest part of the instrument.

Now, when the specific gravity of a fluid is to be determined, the fluid is put into a glass jar, or other convenient vessel, and the gravimeter is set to float in it; then the specific gravity of the fluid is indicated by the number of the divisions of the stem *ac* which remain above the surface of the fluid; or (which amounts to the same thing) by those which remain below that surface; those divisions being made, by trial and adjustment, to represent parts of the whole bulk of the instrument. Suppose, for instance, that the bulk of the whole instrument be equal to 1000 cubic tenths of an inch, and that each of the divisions of the stem represents one of those parts. Then if this instrument be placed first in one fluid and

then in another, and if it be found to sink as far as the 40th division (counting from the top) in one fluid, and as far as the 30th in the other fluid, it is evident that of the 1000 parts of the bulk, 960 have been sunk in the former fluid, and 970 in the latter; therefore, since the specific gravities of those fluids are inversely as the parts immersed, the specific gravity of the former is to that of the latter, as 970 is to 960. If water be one of the fluids, for instance the former, then say, as 970 is to 960, so is one to a fourth proportional, which is the specific gravity of the other fluid when that of water is called unity. But the divisions on most of those instruments are numbered so as to indicate immediately the specific gravity of a fluid in comparison with that of water, which is reckoned one.

Gravimeters of the above-mentioned sort have been made of glass for such fluids as corrode metals; and of metal, which is more durable, for such fluids as have no action upon it. But the peculiar imperfections of the instrument are 1st., it can serve only for those fluids which differ very little in specific gravity; for if the divisions of the stem represent small portions of the bulk of the instrument, then the whole length of the stem will likewise represent no great part of the whole bulk; hence very little difference of specific gravity can be indicated by all the divisions which are upon it; and if the divisions represent considerably large portions of the instrument, then the instrument will not indicate small differences of specific gravity. 2ndly. The inequalities of the stem, and the small quantity of fluid, which in the common manner of using the instrument can hardly be prevented from adhering to that part of the stem which is just above the fluid, render it inaccurate in a greater or less degree; they are however useful for many common purposes.

GRAVIMETER, (NICHOLSON'S), fig. 7, plate VI.—It does not appear that a better method for finding specific gravities, particularly for the use of the chemist, need be wished for; for this instrument determines the specific weight of both solids and fluids in an easy and expeditious way, and it requires no address in using it. *a* is a hollow ball of brass or copper; *e* is a dish affixed to the ball by a short slender stem *d*; *c* is another dish affixed to the opposite side of the ball by a kind of stirrup. In the instrument actually made, the stem *d* is of hardened steel, $\frac{1}{40}$ of an inch in diameter, and the dish *c* is so heavy as in all cases to keep the stem vertical, when the instrument is made to float in any liquid. The parts are so adjusted that the addition of 1000 grains, in the upper dish *b*, will just sink it in distilled water, at the temperature of 60° of Fahrenheit's thermometer, so that the surface shall intersect the middle of the stem *d*. Let it now be required to find the specific gravity of any fluid. Immerse the instrument therein, and by placing weights in the dish *b* cause it to float, so that the middle of its stem *d* shall be cut by the surface of the fluid. Then, as the known weight of the instrument added to 1000 grains, is to the same known weight added to the weights used in producing the last equilibrium, so is the weight of a quantity of distilled water displaced by the floating instrument to the weight of an equal bulk of the fluid under consideration. And these weights give the ratio of the specific gravities. Again, let it be required to find the specific gravity of a solid body less than 1000 grains. Place the instrument in distilled water, and put the body in the dish *b*. Make the adjustment of sinking the instrument to the middle of the stem, by adding weights in the same dish. Take those weights from 1000 grains, and the remainder will be the

weight of the body. Place now the body in the lower dish *c*, and add more weight in the upper dish *b*, till the adjustment is again obtained. The weight last added will be the loss the solid sustains by immersion, and is the weight of an equal bulk of water. Consequently the specific gravity of the solid compared with water, is as its weight to the loss it sustains by immersion.

GRAVIMETER, (GUYTON'S.) — Nicholson's gravimeter has hitherto been constructed of metal, hence it cannot be used for acids; to obviate this objection, Guyton has modified the construction of the instrument so that it may be made easily of glass; his instrument is of a cylindric form, being that which requires the smallest quantity of the fluid, and is on that account preferable, except so far as it is necessary to deviate for the security of a perpendicular position.

Like the instrument of Nicholson, it carries two basins; the one superior, at the extremity of a thin stem; towards the middle of which the fixed point of immersion is marked. The other lower basin terminates in a point; it contains the ballast, and is attached to the cylinder by two branches. The moveable suspension by means of a hook has the inconvenience of shortening the lever which is to secure the vertical position.

The cylinder is 0.71 inches in diameter, and 6.85 inches in length. It carries in the upper basin an additional constant weight of five *grammes*. These dimensions might be increased, so as to render it capable of receiving a much more considerable weight; but it will hereafter be shown that this is unnecessary.

Guyton has added a piece which he calls the diver (*plongeur*), because in fact it is placed in the lower basin when used, and consequently is entirely immersed

in the fluid.* It is a bulb of glass, loaded with a sufficient quantity of mercury, in order that its total weight may be equal to the constant additional weight, added to the weight of the volume of water displaced by this piece.

It will readily be understood, that the weight being determined at the same temperature at which the instrument was originally adjusted, it will sink to the same mark on the stem, whether it be loaded with a constant additional weight in the upper basin, or whether the effect of this weight be produced by the additional piece in the lower dish.

From this explanation there will be no difficulty in deducing how this instrument may be adapted to every case of practice.

It may be used for solids or fluids. It is in fact the hydrometer of Nicholson, from which it differs in no respect. The only condition will be, as in his instrument, that the absolute weight of the body to be examined shall be rather less than the constant additional weight, which in this instrument is 115 grains. For liquids of less specific gravity than water, the instrument, without the additional weight above, weighs about 459 grains in the dimensions before laid down. It would be easy to limit its weight to the utmost accuracy. We have therefore the range of one-fifth of buoyancy, and consequently the means of ascertaining all the intermediate densities from water to the most highly rectified spirit of wine, which is known to bear in this respect the ratio of eight to ten with regard to water. When liquids of greater specific gravity than water are to be tried, the constant weight being

* As we have no word in the English which can with propriety be used as the translation of the word *plongeur*, we shall take the liberty to call this weight the additional piece.

applied below, by means of the additional piece, which weighs about 138 grains, the instruments can receive in the upper basin more than four times the usual additional weight, without losing the equilibrium of its vertical position. In this state it is capable of shewing the specific gravity of the most concentrated acids. It possesses another property common to the instrument of Nicholson, namely, that it may be used as a balance to determine the absolute weight of such bodies as do not exceed its additional load. Lastly, the purity of the water being known, it will indicate the degrees of rarefaction and condensation in proportion to its own bulk. The additional piece for the lower basin requires some attention to make it perfectly agree with the constant upper weight, as to the immersion of the instrument. But this object may, by careful adjustment, be ascertained with the utmost certainty and accuracy. The bulb of glass is for this purpose drawn out to a fine point; a sufficient quantity of mercury is introduced to sink it, and the aperture closed with a morsel of wax. The bulb being then placed in the lower basin of the instrument, the upper basin is to be loaded until the mark on the stem becomes accurately coincident with the surface of the water. The sum of the weights added above is precisely equal to that of the quantity of mercury necessary to be added to that in the glass bulb; which done, nothing more is necessary than to seal the point by fusion, taking care not to change its bulk.

Though this instrument is rather delicate in form, it has no other imperfection than the natural brittleness of the material, which must necessarily be used for experiments with saline and acid liquors.

Nothing more remains but to render it portable. This object is sufficiently obtained by means of a case in which all the delicate parts are secured from pressure, and the

heavier parts supported in such a manner as to resist the excess of motion they are capable of acquiring by virtue of their mass. This last circumstance is frequently overlooked by such workmen as are employed in the packing of instruments; whence it necessarily follows, that some strain or fracture must be produced when matters of very unequal density are exposed to receive a common impulse.

The method of securing this instrument in its case will be better understood from fig. 4, plate VI., than from the most extended verbal description.

The condition of hermetically sealing the additional piece without changing its volume, necessarily requires that the part near the aperture should be very thin. Hence it has sometimes happened that the point was broken without any external blow, but merely in consequence of the motion of the mercury contained within. A similar glass bulb might indeed be added; but this constitutes but a small part of the remedy. For it is necessary to adjust the instrument again to preserve the property of measuring the specific gravity of the denser fluids, and it has been found that this operation was not exempt from difficulties when the desired degree of precision was to be sought.

This inconvenience is remedied by substituting in the place of the glass bulb loaded with mercury a small mass of solid glass, as the stopper of a bottle, which is first brought to the proper form by grinding, and afterwards carefully diminished, until, when placed in the lower basin of the instrument, its immersion in distilled water at the required degrees of temperature and pressure shall be exactly the same as when the instrument is floated in the same liquid with its constant additional weight in the upper basin only.

By this means there is a certainty of acquiring the utmost degree of precision at first trial; because the whole process is reduced to the mere adjustment of a weight.

The following is the method for applying this gravimeter to find the specific gravity of any substance whatever, without requiring distilled water, or the thermometer or barometer, or any subsequent correction.

The gravimeter being supposed to be well regulated, let x represent the specific gravity sought; b the additional weight necessary to sink the instrument to the mark in the unknown fluid; c the weight placed with the solid in the upper basin immerses the instrument to the mark; d the additional weight to produce the same effect when the body is in the lower basin Π the specific gravity of distilled water, at the temperature of 12.5 degrees of the decimal thermometer, and the pressure of 757.7 millimeters = 1; Π' the specific gravity of the water made use of.

The following formula gives the solution*: $x = \frac{(b-c) \Pi'}{d-c}$

The value of Π' is first to be found, which is greater than unity when the water made use of is heavier than distilled water, and in the contrary case is a fraction.

Let P represent the weight of the gravimeter without any additional weight in the upper dish. For the lower

* For the sake of those who are unacquainted with symbols, I shall here give the rule in words at length: From the weight in the upper dish, when the instrument is properly immersed in the unknown fluid, take the weight which is placed with the body in the same scale at the like adjustment. The remainder is the absolute weight of the solid. Multiply this by the specific gravity of the fluid, and reserve the product.

additional piece acts only by its residual weight, and this must vary with the fluid, it is clear that it must be considered as part of the instrument, and enter into the value of P whenever it is used. In fact the gravimeter with this piece is an instrument perfectly distinct from that in which it is not used, and the adjustment may then be made as well, and perhaps more easily, by a constant small weight in the upper dish, as by the very delicate process recommended by Guyton. V the constant volume of the immersed part; a the additional constant weight in the upper basin, or that which immerses it to the mark in distilled water π ; and we shall have $P + a = V \pi$;

$$\text{whence } V = \frac{P + a}{\pi}$$

Again b represents the weight more or less than a , which must be substituted to produce the same immersion in another liquor different from distilled water.

$$\text{We shall therefore have } \pi' = \frac{P + b}{V} = \frac{P + b}{P + a}.$$

The value of π' being found, every thing else is known; nothing more being necessary than to substitute this value in the formula.

We are persuaded that philosophers will immediately perceive the advantages of this method. Distilled water was wanting; but this practice renders it unnecessary. Even if distilled water were at hand, it would seldom happen that the times of the standard temperature and pressure would agree with those of the experiment; and when an artificial temperature is produced, it is subject to vary during the course of the experiment. All these difficulties are removed; and even when distilled water is at hand, water containing a small portion of a neutral salt is preferred. Two motives justify this preference. 1st. It

is more convenient to add some small weight to the constant additional weight, than to compose a less by a series of sub-multiples. 2d. By making use of a liquid at the temperature of the surrounding air, it is evidently less exposed to such variations. These circumstances are more favourable to accuracy in the results.

Fig. 10, plate VI., represents the gravimeter, *a* the lower basin, *b* the upper basin, *c* the point of immersion marked on a thin piece of glass in the inside of the stem marked *x*, the piece called *plongeur*, which is placed in the lower basin *a*, when experiments are made on fluids of greater density than water. Fig. 5, the gravimeter in the cylindric vessel filled with water, in which it floats immersed to the mark *c*, by means of the additional constant weight *d*. It is convenient to choose a vessel of such a depth that the instrument may be at liberty to float, at the level of the mark, or even beneath it, without its being possible that the bottom of the upper basin should ever descend to the surface of the water. Fig. 4, the gravimeter in its case. *A* The cylindrical part of the instrument lodged in a groove in the case, and secured above by the two projections *e e* which leave the stem at liberty. It is secured at the middle by the brass button *f*, and is pressed below by a piece of cork, which rests on a fixed block; *i*, is a sliding piece and screw to support the ballast-piece, and prevent the branches from being endangered by any internal movement of the mercury; *k*, the additional ballast-piece, or *plongeur* in its separate cell; *l*, the constant additional weight placed in a cell cut in the solid wood, and cleared out at the sides, so that it may be conveniently taken up when wanted; *m*, the inner surface of the cover hollowed out at *n* to receive without friction the projecting part of the upper basin. A paper is past on the inner surface of the cover, to shew

the weight of the gravimeter with or without the additional ballast-piece, and the volume of water it displaces in either case, which are often required to be accurately known.

GUN-BARREL APPARATUS.—This name is usually given to a gun-barrel when combined with a furnace. Thus fig. 42, plate I., is the gun-barrel apparatus for a fluid or gas to pass through an ignited gun-barrel; for example, let us suppose we wish to pass carbonic acid through the tube. For this purpose make a gun-barrel *b*, to pass through a furnace, taking care to incline it at the narrowest part; adjust to one of its extremities a bent tube, and let the other extremity of the barrel terminate in a tube *c*, combined with a tube of safety. Introduce one extremity of the tube, as shown in the design, under a bell in the pneumatic basin. When the apparatus is thus disposed and well luted, bring the gun-barrel to a red heat, and when thoroughly red-hot, pour diluted muriatic acid into the hydrostatic funnel, fixed into the two-necked bottle, drop by drop, to disengage the carbonic acid from marble or chalk put into the two-necked bottle for that purpose.

Fig. 14, plate II., shows a gun-barrel apparatus for exhibiting the production of hydrogen gas, by the decomposition of water. The portable furnace is similar to the universal furnace, described page 133. It is made of hammered sheet iron, lined with fire-bricks. The height of the body of the furnace is eighteen inches, its inner diameter measures eight inches. In the front of the furnace are three openings, *a a a*, perpendicularly over each other, furnished with doors. The lower door closes the ash-pit, and serves to regulate the heat at pleasure by opening or shutting it more or less accordingly, *d* is the chimney, which may be elongated by an additional tube, and then directed into the fire-place of the apartment. If a very

intense heat be required, this tube or chimney of the furnace should be at least five or six feet high. Let a gun-barrel, $x x$, having its chamber or breech removed, pass through the furnace, taking care to incline the barrel at the narrowest part; adjust to its upper extremity a small glass retort y , charged with water, and let the other extremity terminate in a tube w , introduced under a receiver p , in the pneumatic trough q . When the apparatus is thus disposed, and well luted, light a fire in the furnace, and bring the gun-barrel to a red heat; and, when thoroughly red-hot, make the water in the retort y , boil; the vapour, when passing through the red-hot tube, will yield hydrogen gas abundantly.

HOOPS, fig. 3, plate XVI.—Wooden hoops, covered with strips of cloth, are convenient for steadily supporting receivers, retorts, basins, and other round bottomed vessels.

HYDROMETER, FOR SALTS, (BEAUME'S,) fig. 10, plate VII.—This hydrometer, though not a very correct instrument, resembles the common gravimeter, it is often employed by manufacturers for ascertaining the specific gravities of saline fluids. It consists of a graduated glass tube ballasted at the lower end by a small quantity of mercury, which keeps it continually in a vertical position. When plunged into distilled water, it stops at the point marked zero: the upper graduations express the different degrees to which it sinks in the lightest liquids; the lower marks the degrees to which it rises in the heaviest liquids.

There are two hydrometers of Beaumé. A single instrument would in strictness suffice to indicate the density of every liquid from the lightest alcohol to the heaviest acid, which would include a range of actual specific

gravity from about .8 to 2. (water being taken as 1.) But an instrument of this kind must be either inconveniently long, or the stem must be very wide, and the degrees too minute for tolerable accuracy. Beaumé therefore very judiciously divided it into two scales, one of which is the hydrometer for spirit and liquors lighter than water, and the other the hydrometer for salts or liquids heavier than water. He has further distinguished them by inverting the scales, that is, in the instrument for salts the 0. or zero is at distilled water, and the numbers increase with the *increasing* density of the liquors for which it is used ; whereas in the instrument for spirit, the numbers increase from the zero with the *decreasing* density. Hence it is necessary to describe these two instruments separately.

The hydrometer for saline fluids was made by Beaumé in the following way : the instrument was first immersed in water at a temperature of 18.75° Reaum. \equiv about 50° Fahr. and loaded with mercury dropped into the bulb till it sunk so low that only the very top of the stem was out of water, which point was marked as the 0. of the scale. The instrument was then removed to a solution of common salt, containing 15 parts (by weight) of salt to 85 parts of water, and the height to which it floated was marked on the stem as 15° of the scale. The interval between these two points of immersion being therefore considered as 15 degrees, the scale was extended to any required number, merely by marking off with compasses an equal length of the stem, and the whole was farther subdivided in the same way. Beaumé considered therefore that every degree of the instrument indicated a density of liquid equal to that of a solution of common salt, in which the number of parts of salt in 100 parts, by weight of the solution, was equal to the same number on

the scale at which the instrument floated. But as the diameter of the stem is seldom equal throughout, he proposes to remedy the incorrectness produced by this circumstance, where greater accuracy is required, by immersing the instrument successively in solutions containing 5, 10, 15, &c. per cent. of salt, and marking these points as 5, 10, 15, &c. on the scale, or, to be still more accurate, all the individual degrees may be found by actual experiment. In fact, even where the stem of the instrument is perfectly cylindrical, this would be the only way to ensure perfect accuracy, as a division of equal distances on the scale would not precisely correspond with an equal increase of the per centage of salt in the solution.

The scale of this instrument does not properly extend higher than about 30° as this is the point of saturation of water with salt, but it may be lengthened at pleasure by marking off equal distances on the scale.

The following table of correspondence between Beaumé's hydrometer for salts and the actual expression of specific gravity has been calculated by Mr. Nicholson, for every third degree (Phil. Journ. 4to. vol. I. page 38.) from the datum of Morveau that the 66th degree corresponds with 1.848 specific gravity.

BEAUMÉ'S HYDROMETER FOR SALTS.

at a temperature of 55° Fahr.		at a temperature of 55° Fahr.	
<i>Beaumé.</i>	<i>Nicholson.</i>	<i>Beaumé.</i>	<i>Nicholson.</i>
1=Sp. Gr.	1.000	10=Sp. Gr.	
2		12	1.089
3	1.020	14	
4		15	1.114
5		16	
6	1.040	18	1.140
7		20	
8		21	1.170
9	1.064	22	

BEAUMÉ'S HYDROMETER FOR SALTS CONTINUED.

at a temperature of 55° Fahr.

Beaumé. *Nicholson.*

24=Sp. Gr. 1.200

26

27 1.230

28

29

30 1.261

31

32

33 1.295

34

35

36 1.333

37

38

39 1.373

at a temperature of 55° Fahr.

Beaumé. *Nicholson.*

40=Sp. Gr.

41

42 1.414

43

45 1.455

48 1.500

51 1.547

54 1.597

57 1.659

60 1.717

63 1.779

66 1.848

69 1.920

72 2.000

HYDROMETER FOR SPIRIT, (BEAUME.)—The hydrometer of Beaumé for spirit is constructed exactly on the same principle as the hydrometer for salts, and the mode of graduation is also the same, that is, by a solution of salt, and not by mixtures of alcohol and water of different densities. In this hydrometer the zero is placed not at the point to which the stem sinks in distilled water, but at the point to which it falls in a mixture of 10 parts of salt and 90 of water. The interval between this point and that of distilled water is marked on the scale as 10 degrees, and this scale is continued upwards on the stem simply by measuring equal portions by the compasses. The 10th degree of the spirit hydrometer corresponds with the 0. of the salt hydrometer, and it is certainly a defect that the ingenious inventor should have introduced this deviation from what is obviously the natural zero in each scale, namely, the point of immersion in distilled water; since it was as easy to obtain a measure for 10 degrees of the scale of the spirit hydrometer

by beginning the notation 10 degrees below zero as at this point.

The correspondence between Beaumé's spirit hydrometer and the real expression of specific gravity has also been calculated by Mr. Nicholson, and on the following data: viz. Beaumé found that spirit of wine of .842 specific gravity at 32° Fahr. gave 37 degrees of his hydrometer; and that a mixture of two parts, by weight of this spirit with 30 of water, gave 12 degrees of the hydrometer at the same temperature. This mixture is found by Gilpin's tables to be = 9915 specific gravity at this temperature, and these terms, viz. .842 and .9915 become .832 and .9905 at 55° Fahr. or 10. Reaum. the standard temperature of the graduation of these instruments.

BEAUMÉ'S HYDROMETER FOR SPIRIT.

at a temperature of 55° Fahr.

at a temperature of 55° Fahr.

Beaumé. *Nicholson.*

Beaumé. *Nicholson.*

10 = Sp. Gr. 1.0000

25 = Sp. Gr. .897

11 .990

26 .892

12 .985

27 .886

13 .977

28 .880

14 .970

29 .874

15 .963

29½

16 .955

30 .871

16½

31 .867

17 .949

32 .856

18 .942

33 .852

19 .935

34 .847

19½

35 .842

20 .928

36 .837

21 .922

37 .832

22 .915

38 .827

23 .909

39 .822

24 .903

40 .817

HYDROMETER FOR BEER AND MALT-WORT.—See
SACCHAROMETER.

HYDROMETER FOR SPIRITOUS LIQUORS, (SYKES'S.)

—By the excise laws at present existing in this country, the various degrees of strength of brandy, rum, arrack, gin, whiskey, and other spiritous liquors, chiefly composed of little else than spirit of wine, are determined by the quantity of alcohol of a given specific gravity contained in the spirituous liquor of a supposed unknown strength. The great public importance of this subject in this country, where the consumption of spiritous liquors adds a vast sum to the public revenue, has been the means of instituting many very interesting series of experiments on this subject. The hydrostatic instrument used for that purpose by the Customs and officers of the Excise, is called Sykes's hydrometer. [George III. c. xxviii, May 1818.—“An Act for establishing the use of Sykes's hydrometer in ascertaining the strength of spirit,” which has now superseded the instrument called Clark's hydrometer, heretofore in use.]

The specific gravity or strength of the legal standard spirit of the Excise, is technically called *proof*, or *proof spirit*. “This liquor (not being spirit sweetened, or having any ingredient dissolved in it, to defeat the strength thereof), at the temperature of 51° Fahr. weighs actually $\frac{1}{13}$ th parts of an equal measure of distilled water;” and with this spirit the strength of all other spirituous liquors are compared according to law.

The strength of brandy, rum, arrack, gin, or other spirituous liquors, weaker than *proof*, or below *proof*, is estimated by the quantity of water which would be necessary to bring the spirit up to proof.

It is by no means an easy undertaking to determine the strength or relative value of spirits with accuracy for commercial purposes. The following requisites must be

obtained before this can be well done : the specific gravity of a certain number of mixtures of alcohol and water must be taken so near each other, as that the intermediate specific gravities may not perceptibly differ from those deduced from the supposition of a mere mixture of the fluids ; the expansions or variations of specific gravity in these mixtures must be determined at different temperatures ; some easy method must be contrived of determining the presence and quantity of saccharine or oleaginous matter which the spirit may hold in solution, and the effect of such solution on the specific gravity ; and lastly, the specific gravity of the fluid must be ascertained by a proper floating instrument with a graduated stem, or set of weights ; or, which may be more convenient, with both.

The strength of brandy, rum, or arrack, in commerce is frequently judged by the phial, or by burning. The phial proof consists in agitating the spirit in a bottle, and observing the form and magnitude of the bubbles that collect round the edge of the liquor, technically termed the *bead*, which are larger the stronger the spirit. It is not difficult, however, to produce this appearance by various simple additions to weak spirit.* The proof by burning is very fallacious ; because the magnitude of the flame, and quantity of residue, in the same spirit, vary greatly with the form of the vessel it is burned in. If the vessel be kept cool, or suffered to become hot, if it be deeper or shallower, the results will not be the same in each case. It does not follow, however, but that manufacturers and purchasers of spirits, may in many instances receive considerable information from these signs, in circumstances exactly alike,

* A Treatise on the Adulteration of Food, and methods of detecting them, page 249.

and in the course of operations wherein it would be inconvenient to recur continually to experiments of specific gravity.

The importance of this object, as well for the purposes of revenue as of commerce, induced the British government to employ Sir Charles Blagden to institute a very minute and accurate series of experiments. These may be considered as fundamental results; for which reason, we shall give a summary of them in this place, from the *Philosophical Transactions* for 1790.

The first object to which the experiments were directed was to ascertain the quantity and law resulting from the mutual penetration of water and spirit.

All bodies in general expand by heat; but the quantity of this expansion, as well as the law of its progression, is probably not the same in any two substances. In water and spirit they are remarkably different. The whole expansion of pure spirit from 30° to 100° of Fahrenheit's thermometer is not less than 1-25th of its whole bulk at 30° ; whereas that of water, in the same interval, is only 1-145th of its bulk. The laws of their expansion are still more different than the quantities. If the expansion of quicksilver be, as usual, taken from the standard, (our thermometers being constructed with that fluid), the expansion of spirit is, indeed, progressively increasing with respect to that standard, but not much so within the above-mentioned interval; while water kept from freezing to 30° , which may easily be done, will absolutely contract as it is heated for ten or more degrees, that is, 40° or 42° of the thermometer, and will then begin to expand as its heat is augmented, at first slowly, and afterwards gradually more rapidly, so as to observe upon the whole a very increasing progression. Now, mixtures of these two substances will, as may be supposed, approach to the less

or the greater of these progressions, according as they are compounded of more spirit or more water, while their total expansion will be greater, according as more spirit enters into their composition ; but the exact quantity of the expansion, as well as law of the progression, in all of them, can be determined only by trials. These were, therefore, the two other principal object to be ascertained by experiment. The person engaged to make these experiments was Dr. Dollfuss ; as he could not conveniently get the quantity of spirit he wanted lighter than 825, at 60° Fahr. he fixed upon this strength as the standard for alcohol.

These experiments of Dr. Dollfuss were repeated by Mr. Gilpin, of the Royal Society ; and as the deductions in this account will be taken chiefly from that last set of experiments, it is proper here to describe minutely the method observed by Mr. Gilpin in his operation. This naturally resolves itself into two parts : the way of making the mixtures, and the way of ascertaining their specific gravity.

1. The mixtures were made by weight, as the only accurate method of fixing the proportions. In fluids of such very unequal expansions by heat, as water and alcohol, if measures had been employed, increasing or decreasing in regular proportions to each other, the proportions of the masses would have been sensibly irregular : now the latter was the object in view, namely, to determine the real quantity of spirit in any given mixture, abstracting the consideration of its temperature. Besides, if the proportions had been taken by measure, a different mixture should have been made at every different degree of heat. But the principal consideration was, that with a very nice balance, such as was employed on this occasion, quantities can be determined to much greater exactness

by weight than by any practicable way of measurement. The proportions were therefore always taken by weight. A phial being provided of such a size as that it should be nearly full with the mixture, was made perfectly clean and dry, and being counterpoised, as much of the pure spirit as appeared necessary was poured into it. The weight of this spirit was then ascertained, and the weight of distilled water required to make a mixture of the intended proportions was calculated. This quantity of water was then added, with all the necessary care, the last portions being put in by means of a well-known instrument, which is composed of a small dish terminating in a tube drawn to a fine point: the top of the dish being covered with the thumb, the liquor in it is prevented from running out through the tube by the pressure of the atmosphere, but instantly begins to issue by drops, or a very small stream, upon raising the thumb. Water being thus introduced into the phial, till it exactly counterpoised the weight, which having been previously computed, was put into the opposite scale, the phial was shaken, and then well stopped with its glass stopple, over which leather was tied very tight, to prevent evaporation. No mixture was used till it had remained in the phial at least a month, for the full penetration to have taken place; and and it was always well shaken before it was poured out to have its specific gravity tried.

2. There are two common methods of taking the specific gravity of fluids; one, by finding the weight which a solid body loses by being immersed in them; the other, by filling a convenient vessel, (see specific gravity bottle), with them, and ascertaining the increase of weight it acquires. In both cases a standard must have been previously taken, which is usually distilled water; namely, in the first method, by finding the weight lost by the solid

body in the water ; and in the second method, the weight of the vessel filled with water. The latter was preferred, for the following reasons :—

When a ball of glass, which is the properest kind of solid body, is weighed in any spirituous or watery fluid, the adhesion of the fluid occasions some inaccuracy, and renders the balance comparatively sluggish. To what degree this effect proceeds is uncertain ; but from some experiments made by Mr. Gilpin with that view, it appears to be very sensible. Moreover, in this method a large surface must be exposed to the air during the operation of weighing, which, especially in the higher temperatures, would give occasion to such an evaporation as to alter essentially the strength of the mixture. It seemed also as if the temperature of the fluid under trial could be determined more exactly in the method of filling a vessel than in the other : for the fluid cannot well be stirred while the ball to be weighed remains immersed in it ; and as some time must necessarily be spent in the weighing, the change of heat which takes place during that period will be unequal through the mass, and may occasion a sensible error. It is true, on the other hand, that in the method of filling a vessel, the temperature could not be ascertained with the utmost precision, because the neck of the vessel employed, containing about ten grains, was filled up to the mark with spirit not exactly of the same temperature, as will be explained presently : but this error, it is supposed, would by no means equal the other, and the utmost quantity of it may be estimated very nearly. Finally, it was much easier to bring the fluid to any given temperature when it was in a vessel to be weighed, than when it was to have a solid body weighed in it ; because in the former case the quantity was smaller, and the vessel containing it more manageable, being readily

heated with the hand or warm water, and cooled with cold water : and the very circumstance, that so much of the fluid was not required, proved a material convenience. The particular disadvantage in the method of weighing in a vessel, is the difficulty of filling it with extreme accuracy ; but when the vessel is judiciously and neatly marked, the error of filling will, with due care, be exceedingly minute. By several repetitions of the same experiments, Mr. Gilpin seemed to bring it within the 1-15000th part of the whole weight.

The above-mentioned consideration induced Dr. Blagden, as well as the gentlemen employed in the experiments, to give the preference to weighing the fluid itself ; and that was accordingly the method practised both by Dr. Dollfuss and Mr. Gilpin in their operations.

The vessel chosen as most convenient for the purpose was a hollow glass ball, terminating in a neck of small bore. That which Dr. Dollfuss used held 5800 grains of distilled water ; but as the balance was so extremely accurate, it was thought expedient, upon Mr. Gilpin's repetition of the experiments, to use one of only 2965 grains capacity, as admitting the heat of any fluid contained in it to be more nicely determined. The ball of this vessel, which may be called the weighing bottle, measured about 2.8 inches in diameter, and was spherical, except a slight flattening on the part opposite to the neck, which served as a bottom for it to stand upon. Its neck was formed of a portion of a barometer tube, .25 of an inch in bore, and about $1\frac{1}{2}$ inch long ; it was perfectly cylindrical, and, on its outside, very near the middle of its length, a fine circle or ring was cut round it with a diamond, as the mark to which it was to be filled with the liquor. This mark was made by fixing the bottle in a lathe, and turning it round with great care, in

contact with the diamond. The glass of this bottle was not very thick ; it weighed 916 grains, and with its silver cap 936.

When the specific gravity of any liquor was to be taken by means of this bottle, the liquor was first brought nearly to the required temperature, and the bottle was filled with it up to the beginning of the neck only, that there might be room for shaking it. A very fine and sensible thermometer was then passed through the neck of the bottle into the contained liquor, which showed whether it was above or below the intended temperature. In the former case the bottle was brought into colder air, or even plunged for a moment into cold water; the thermometer in the mean time being frequently put into the contained liquor, till it was found to sink to the right point. In like manner, when the liquor was too cold, the bottle was brought into warmer air, immersed in warm water, or more commonly held between the hands, till upon repeated trials with the thermometer the just temperature was found. It will be understood, that during the course of this heating or cooling, the bottle was very frequently shaken between each immersion of the thermometer; and the top of the neck was covered, either with the finger, or a silver cap made on purpose, as constantly as possible. Hot water was used to raise the temperature only in heats of 80° and upwards, inferior heats being obtained by applying the hands to the bottle: when the hot water was employed, the ball of the bottle was plunged into it, and again quickly lifted out, with the necessary shaking interposed, as often as was necessary for communicating the required heat to the liquor; but care was taken to wipe the bottle dry after each immersion, before it was shaken, lest any adhering moisture might by accident get into it. The liquor having by these means been brought to the desired

temperature; the next operation was to fill up the bottle exactly to the mark upon the neck, which was done with some of the same liquor, by means of a glass funnel with a very small bore. Mr. Gilpin endeavoured to get that portion of the liquor which was employed for this purpose, pretty nearly to the temperature of the liquor contained in the bottle; but as the whole quantity to be added never exceeded ten grains, a difference of ten degrees in the heat of that small quantity, which is more than it ever amounted to, would have occasioned an error of only 1-30th of a degree in the temperature of the mass. Enough of the liquor was put in to fill the neck rather above the mark, and the superfluous quantity was then absorbed to great nicety, by bringing into contact with it the fine point of a small roll of blotting paper. As the surface of the liquor in the neck would be always concave, the bottom or centre of this concavity was the part made to coincide with the mark round the glass; and in viewing it care was taken, that the near and opposite sides of the mark should appear exactly in the same line, by which means all parallax was avoided. A silver cap, which fitted tight, was then put upon the neck, to prevent evaporation; and the whole apparatus was in that state laid in the scale of the balance, to be weighed with all the exactness possible.

The spirit employed by Mr. Gilpin was furnished to him by Dr. Dollfuss, under whose inspection it had been rectified from rum supplied by government. Its specific gravity, at 60 degrees of heat, was 82514. It was first weighed pure, in the above-mentioned bottle, at every five degrees of heat, from 30 to 100 inclusively. Then mixtures were formed of it, and distilled water, in every proportion, from 1-20th of the water to equal parts of water and spirit; the quantity of water added being suc-

cessively augmented, in the proportion of five grains to one hundred of the spirit; and these mixtures were also weighed in the bottle, like the pure spirit, at every five degrees of heat. The numbers hence resulting are delivered in the following table; where the first column shows the degrees of heat; the second gives the weight of the pure spirit contained in the bottle at those different degrees; the third gives the weight of a mixture in the proportions of 100 parts by weight of that spirit to 5 of water, and so on successively till the water is to the spirit as 100 to 5. They are the mean of three several experiments at least, as Mr. Gilpin always filled and weighed the bottle over again that number of times, if not oftener. The heat was taken at the even degree, as shown by the thermometer, without any allowance in the first instance, because the coincidence of the mercury with a division can be perceived more accurately than any fraction can be estimated; and the errors of the thermometers, if any, it was supposed would be less upon the grand divisions of 5 degrees than in any others. It must be observed, that Mr. Gilpin used the same mixture throughout all the different temperatures, heating it up from 30° to 100° ; hence some small error in its strength may have been occasioned in the higher degrees, by more spirit evaporating than water: but this, it is believed, must have been trifling, and greater inconvenience would probably have resulted from interposing a fresh mixture.

The precise specific gravity of the pure spirit employed was .82514; but to avoid an inconvenient fraction, it is taken, in constructing the table of specific gravities, as .825 only, a proportional deduction being made from all the other numbers. Thus the following table gives the true specific gravity, at the different degrees of heat, of a pure rectified spirit, the specific gravity of which

at 60° is .825, together with the specific gravities of different mixtures of it with water, at those different temperatures.

Real Specific Gravities at the different Temperatures.

Heat.	The pure spirit.	100 grains of spirit to 5 grains of water.	100 grains of spirit to 10 grains of water.	100 grains of spirit to 15 grains of water.	100 grains of spirit to 20 grains of water.	100 grains of spirit to 25 grains of water.	100 grains of spirit to 30 grains of water.	100 grains of spirit to 35 grains of water.	100 grains of spirit to 40 grains of water.	100 grains of spirit to 45 grains of water.	100 grains of spirit to 50 grains of water.
30°	83896	84995	85957	86825	87585	88282	88921	89511	90054	90558	91023
35	83672	84769	85729	86587	87357	88059	88701	89294	89839	90345	90811
40	83445	84539	85499	86361	87134	87838	88481	89073	89617	90127	90596
45	83214	84310	85277	86131	86915	87613	88255	88849	89396	89909	90380
50	82977	84076	85042	8592	86676	87384	88030	88626	89174	89684	90160
55	82736	83834	8482	85664	86441	87150	87796	88393	88945	89458	89933
60	82500	83599	84568	8543	86218	86918	87569	88169	88720	89232	89707
65	82262	83362	84334	8523	85976	86686	87337	87938	88490	89006	89479
70	82023	83124	84092	84951	85736	86451	87105	87705	88254	88773	89252
75	81780	82878	83851	84711	85496	86212	86864	87466	88018	88538	89018
80	81530	82631	83603	84467	85248	85966	86622	87228	87776	88311	88781
85	81291	82396	83371	84243	85036	85757	86411	87021	87590	88120	88609
90	81044	82150	83126	84001	84797	85518	86172	86787	87360	87889	88376
95	80794	81900	82877	83753	84550	85272	85928	86542	87114	87654	88146
100	80548	81657	82639	83513	84038	85031	85688	86302	86879	87421	87915

Real Specific Gravities at the different Temperatures.

Heat.	100 grains of spirit to 55 grains of water.	100 grains of spirit to 60 grains of water.	100 grains of spirit to 65 grains of water.	100 grains of spirit to 70 grains of water.	100 grains of spirit to 75 grains of water.	100 grains of spirit to 80 grains of water.	100 grains of spirit to 85 grains of water.	100 grains of spirit to 90 grains of water.	100 grains of spirit to 95 grains of water.	100 grains of spirit to 100 grs. of water.
30°	91449	91847	92217	92563	92889	93191	93474	93741	93991	94222
35	91241	91640	92009	92355	92680	92986	93274	93541	93790	94025
40	91026	91428	91799	92151	92476	92783	93072	93341	93592	93827
45	90812	91211	91584	91937	92264	92570	92859	93131	93382	93621
50	90596	90997	91370	91723	92051	92358	92647	92919	93177	93419
55	90367	90768	91144	91502	91837	92145	92436	92707	92963	93208
60	90144	90549	90927	91287	91622	91933	92225	92499	92758	93002
65	89920	90328	90707	91066	91400	91715	92010	92283	92546	92794
70	89695	90104	90484	90847	91181	91493	91793	92069	92333	92586
75	89464	89872	90252	90617	90952	91270	91569	91849	92111	92364
80	89225	89639	90021	90385	90723	91046	91340	91622	91891	92142
85	89043	89460	89843	90209	90558	90882	91186	91465	91729	91969
90	88817	89230	89617	89988	90342	90668	90967	91248	91511	91751
95	88588	89003	89390	89763	90119	90443	90747	91029	91290	91531
100	88357	88769	89158	89536	89889	90215	90522	90805	91066	91310

Real Specific Gravities at the different Temperatures.

Heat.	95 grains of spirit to 100 gr. of water.	90 grains of spirit to 100 gr. of water.	85 grains of spirit to 100 gr. of water.	80 grains of spirit to 100 gr. of water.	75 grains of spirit to 100 gr. of water.	70 grains of spirit to 100 gr. of water.	65 grains of spirit to 100 gr. of water.	60 grains of spirit to 100 gr. of water.	55 grains of spirit to 100 gr. of water.	50 grains of spirit to 100 gr. of water.
30°	·94447	·94675	·94920	·95173	·95429	·95681	·95944	·96209	·96470	·96719
35	94249	94484	94734	94988	95246	95502	95772	96048	96315	96579
40	94058	94295	94547	94802	95060	95328	95602	95879	96159	96434
45	93860	94096	94348	94603	94871	95143	95423	95705	95993	96280
50	93658	93897	94149	94414	94683	94958	95243	95534	95831	96126
55	93452	93696	93948	94213	94486	94767	95057	95357	95662	95966
60	93247	93493	93749	94018	94296	94579	94876	95181	95493	95804
65	93040	93285	93546	93822	94099	94388	94689	95000	95318	95635
70	92828	93076	93337	93616	93898	94193	94500	94813	95139	95469
75	92613	92865	93132	93413	93695	93989	94301	94623	94957	95292
80	92393	92646	92917	93201	93488	93785	94102	94431	94768	95111

Real Specific Gravities at the different Temperatures.

Heat.	45 grains of spirit to 100 gr. of water.	40 grains of spirit to 100 gr. of water.	35 grains of spirit to 100 gr. of water.	30 grains of spirit to 100 gr. of water.	25 grains of spirit to 100 gr. of water.	20 grains of spirit to 100 gr. of water.	15 grains of spirit to 100 gr. of water.	10 grains of spirit to 100 gr. of water.	5 grains of spirit to 100 gr. of water.
30°	·96967	·97200	·97418	·97635	·97860	·98108	·98412	·98804	·99334
35	96847	97086	97319	97556	97801	98076	98397	98804	99344
40	96706	96967	97220	97472	97737	98033	98373	98795	99345
45	96563	96840	97110	97384	97666	97980	98338	98774	99338
50	96420	96708	96995	97284	97589	97920	98293	98745	99316
55	96272	96575	96877	97181	97500	97847	98239	98702	99284
60	96122	96437	96752	97074	97410	97771	98176	98654	99244
65	95962	96288	96620	96959	97309	97688	98106	98594	99194
70	95802	96143	96484	96836	97203	97596	98028	98527	99134
75	95638	95987	96344	96708	97086	97495	97943	98454	99066
80	95467	95826	96192	96568	96963	97385	97845	98367	98991

From these tables, when the specific gravity of any spirituous liquor is ascertained, it will be easy to find the quantity of rectified spirit of the above mentioned standard, contained in any given quantity of it, either by weight or measure.

Dr. Blagden concludes this part of the report with observing, that as the experiments were made with pure spirit and water, if any extraneous substances are contained

in the liquor to be tried, the specific gravity in the tables will not give exactly the proportions of water and spirit in it. The substances likely to be found in spirituous liquors, where no fraud is suspected, are essential oils, sometimes empyreumatic, mucilaginous or extract matter, and perhaps some saccharine matter. The effect of these, in the course of trade, seems to be hardly such as would be worth the cognizance of the excise, nor could it easily be reduced to certain rules. Essential and empyreumatic oils are nearly of the same specific gravity as spirit, in general rather lighter, and therefore, notwithstanding the mutual penetration, will probably make little change in the specific gravity of any spirituous liquor in which they are dissolved. The other substances are all heavier than spirit; hence they will make spirituous liquors appear less strong than they really are.

The following table drawn up by Dr. Thomson, exhibits the specific gravity at every degree of temperature from 30° to 80° of a mixture of 100 parts of Gilpin's standard alcohol, and 65.6486 parts of water by weight. This mixture constitutes spirits 8 per cent. above proof, according to the language of Sykes's hydrometer, or 1 to 10 above proof by Clarke's hydrometer.

Temp.	Sp. Gr.	Temp.	Sp. Gr.	Temp.	Sp. Gr.	Temp.	Sp. Gr.
30°	0.92206	43°	0.91659	56°	0.91090	69°	0.90516
31	0.92165	44	0.91616	57	0.91046	70	0.90474
32	0.92124	45	0.91573	58	0.91003	71	0.90428
33	0.92082	46	0.91531	59	0.90960	72	0.90382
34	0.92040	47	0.91488	60	0.90917	73	0.90336
35	0.91998	48	0.91445	61	0.90873	74	0.90290
36	0.91956	49	0.91403	62	0.90829	75	0.90243
37	0.91914	50	0.91359	63	0.90785	76	0.90197
38	0.91872	51	0.91314	64	0.90741	77	0.90151
39	0.91830	52	0.91269	65	0.90697	78	0.90104
40	0.91788	53	0.91224	66	0.90653	79	0.90058
41	0.91745	54	0.91176	67	0.90609	80	0.90012
42	0.91702	55	0.91134	68	0.90564		

HYDROMETER FOR SPIRIT, (STOKES'S).—This instrument possesses quite sufficient accuracy for all common, practical purposes, it is cheap, and of very easy application, it requires the assistance neither of a book of tables, of a sliding rule, nor of weights. By means of it the value of a given spirituous liquor may be ascertained to one-fourth of a degree above or below proof; and hence it is of great service to those dealers in spirituous liquors who either object to the cost of Sykes's instrument, or who feel embarrassed in making the calculations required for the correct employment of it.

The instrument consists of a spherical glass ball, with a short tube at the bottom, connected with a smaller bulb in which is contained quicksilver requisite to bring the instrument to its real weight so as to correspond with the scale. The stem is about seven inches long, and contains a double scale, one coloured, the other white or plain. These scales are drawn on paper, which is introduced into the hollow of the stem, and being fixed by means of cement at the lower end, is afterwards prevented from derangement or injury by hermetically sealing the mouth of the stem. The plain scale of the hydrometer shows the per-centage of spirit above or below proof, and can be extended, if required (upward) to 70 per cent. over proof, or (downward) to water. The thermometer is divided into 15 degrees more or less, and each division subdivided into halves and quarters, computed from zero or 0 upward, and from the same point downward, to the extent of the tube. The words '*add*,' below zero, and '*subtract*' above the same, show the number of degrees to be added to, or subtracted from the line of indication on the coloured scale of the hydrometer; such number being the variation of the temperature from the point zero,

above or below, is thus used to ascertain the real from the apparent indication.

To use this instrument, fill a glass cylinder nearly with the spirit which is to be tried, and immerse the hydrometer therein to the depth of the ball; suffer it then to sink until it finds its resting point. When the instrument becomes stationary, observe what number of degrees marked on the *coloured* part of the scale within the stem corresponds with the surface of the spirit—suppose it be $27\frac{3}{4}$; place this number on a slip of paper: this done, the hydrometer is to be taken out, and the thermometer dipped into the spirit, in order to ascertain the temperature of the latter. Observe now the point or degree at which the quicksilver settles—suppose it to be $2\frac{1}{2}$ *below* zero or 0; place this number down also on the slip of paper under

$$27\frac{3}{4}$$

the $27\frac{3}{4}$, and *add* them together thus: $2\frac{1}{2}$, making a sum

$$\underline{30\frac{1}{4}}$$

of $30\frac{1}{4}$. Look, in the next place, for $30\frac{1}{4}$ on the coloured scale, in a line with which, on the white or plain scale, will be found 18.2. This last number is the per-centage *above proof* of the spirit, and corresponds exactly with what would be determined by Sykes's hydrometer.

But suppose, secondly, the resting point of the hydrometer and corresponding surface of the spirit be 22.0 on the coloured scale, and on the hydrometer being again drawn and the thermometer immersed, that the quicksilver in the latter should stand at $2\frac{1}{4}$ *above* 0, place these two numbers down as before, and *subtract* the lower from

$$22.0$$

the upper, thus: $2\frac{1}{4}$, the number remaining indicates

$$\underline{19\frac{3}{4}}$$

the strength of the spirit; which at $19\frac{3}{4}$, as in this

example, is exactly of *proof strength*, as shown by Sykes's hydrometer.

Thirdly, suppose the indication or surface number of degrees on the coloured scale, when the hydrometer is at its subsiding point, to be $14\frac{1}{4}$, and the quicksilver in the thermometer (on its subsequent immersion) to settle at 0; it being obvious here that there is no number either to add or to subtract, a reference to the white or plain scale alone will be sufficient. The per-centage or strength of the spirit will, in this case, be indicated by that number of degrees on the plain scale which stands level with the surface of the spirit; and the strength of the latter will, in this example, be found to be 10 per cent. under proof.

HYDROMETRICAL BEADS.—See **AEROMETRICAL BEADS**, page 40.

HYDROSTATIC FUNNEL.—See page 122.

HYDROSTATIC BALANCE. — See **BALANCE**, page 46.

HYGROMETER, (SAUSSURE'S.)—An instrument to measure the degrees of dryness or moisture of the atmosphere. There are divers sorts of hygrometers; for whatever body either swells or shrinks, by dryness or moisture, is capable of being formed into an hygrometer. Such are woods of most kinds, such also is catgut, the beard of a wild oat, &c. Hygrometers acting on other principles have been contrived, by Leslie, Wilson, and Daniell, as will be shown presently.

All bodies that are susceptible of imbibing water have a greater or less disposition to unite themselves with that fluid, by the effect of an attraction similar to chemical

affinity. If we plunge into water several of these bodies, such as wood, a sponge, paper, &c. they will appropriate to themselves a quantity of that liquid, which will vary with the bodies respectively; and, as in proportion as they tend towards the point of saturation, their affinity for the water continues to diminish, when those which have most powerfully attracted the water, have arrived at the point, where their attractive force is found solely equal to that of the body, which acted most feebly upon the same liquid, there will be established a species of equilibrium between all those bodies, in such manner, that at this term the imbibing will be stopped. If there be brought into contact two wetted or soaked bodies, whose affinities for water are not in equilibrio; that whose affinity is the weakest, will yield of its fluid to the other, until the equilibrium is established; and it is in this disposition of a body to moisten another body that touches it, that what is called humidity properly consists. Of all bodies, the air is that of which we are most interested to know the different degrees of humidity, and it is also towards the means of procuring this knowledge, that philosophers have principally directed their researches; and hence the various kinds of instruments that have been contrived to measure the dryness of the air. A multitude of bodies are known, in which the humidity, in proportion as it augments or diminishes, occasions divers degrees of dilatation or of contraction, according as the body is inclined to one or other of these effects, by reason of its organization, of its texture, or of the disposition of the fibres of which it is the assemblage. For example, water, by introducing itself within cords, makes the fibres twist and become situated obliquely, produces between those fibres such a separation, as causes the cord to thicken or swell, and, by a necessary consequence, to

shorten. The twisted threads, of which cloths are fabricated, may be considered as small cords, which experience, in like manner, a contraction by the action of humidity; whence it happens, that cloths, especially when wetted for the first time, contract in the two directions of their intersecting threads; paper, on the contrary, which is only an assemblage of filaments very thin, very short, and disposed irregularly in all directions, lengthens in all the dimensions of its surface, in proportion as the water, by insinuating itself between the intervals of those filaments, acts by placing them further asunder, proceeding from the middle towards the edges. Hence different bodies have been employed successively in the construction of hygrometers, chosen from among those in which moisture produces the most sensible motions. Philosophers have sought also to measure the humidity of the air by the augmentation of weight undergone by certain substances, such as a tuft of wool, or portions of salt, by absorbing the water contained in the air. But, besides that these methods are in themselves very imperfect, the bodies employed were subject to alterations which would make them lose their hygrometric quality more or less promptly; they had, therefore, the double inconvenience of being inaccurate, and not of long service.—To deduce from hygrometry real advantages, the instrument must be put in a state of rivalry with the thermometer, by presenting a series of exact observations, such as may be comparable under different circumstances. The celebrated Saussure, to whom we are indebted for a very estimable work on hygrometry, has attained the accomplishment of this object by a process of which we shall attempt to give some idea. The principal piece in his hygrometer is a hair, which Saussure first causes to undergo a preparation, the design of which is to divest it of a kind of oiliness

that is natural to it, and that secures it to a certain point, from the action of humidity. This preparation is made at the same time upon a certain number of hairs forming a tuft, the thickness of which need not exceed that of a writing pen, and contained in a fine cloth serving them for a case. The hairs thus enveloped are immersed in a long-necked phial full of water, which holds in solution nearly a hundredth part of its weight of sulphate of soda, this water is made to boil nearly thirty minutes. The hairs are then passed through two vessels of pure water, while they are boiling; afterwards they are drawn from their wrapper, and separated; then they are suspended to dry in the air; after which there only remains to make choice of those which are the cleanest, softest, most brilliant, and most transparent. It is known that humidity lengthens the hair, and that the process of drying shortens it. To render both these effects more perceptible, Saussure attached one of the two ends of the hair to a fixed point, and the other to the circumference of a moveable cylinder, that carries at one of its extremities a light index or hand. The hair is bound by a counter-weight of about three grains, suspended by a delicate silk, which is rolled in a contrary way about the same cylinder. In proportion as the hair lengthens or shortens, it causes the cylinder to turn in one or the other direction, and by a necessary consequence, the little index turns likewise, the motions of which are measured on the circumference of a graduated circle, about which the index performs its revolution as in common clocks. In this manner a very small variation in the length of the hair becomes perceptible, by the much more considerable motion that it occasions in the extremity of the index; and it will be easily conceived, that equal degrees of expansion, or of contraction in the hair, answer to equal arcs described by the extremity of the

index. To give to the scale such a basis as may establish a relation between all the hygrometers that are constructed upon the same principles, Saussure assumes two fixed terms, one of which is the extreme of humidity, and the other that of dryness : he determines the first by placing the hygrometer under a glass receiver, the whole interior surface of which he had completely moistened with water ; the air being saturated by this water, acts by its humidity upon the hair to lengthen it. He moistened anew the interior of the receiver, as often as it was necessary ; and he knew that the term of extreme humidity was attained, when, by a longer continuance under the receiver, the hair ceased to extend itself. To obtain the contrary limit of extreme dryness, the same philosopher made use of a hot and well-dried receiver, under which he included the hygrometer, with a piece of iron plate, likewise heated and covered with a caustic alkali. This salt, by exercising its absorbent faculty upon the remaining humidity in the surrounding air, causes the hair to contract until it has attained the ultimate limit of its contraction. The scale of the instrument is divided into hundred degrees. The zero indicates the limit of extreme dryness, and the number one hundred that of extreme humidity. The effects of moisture and of dryness upon the hair, are modified by those of heat, which act upon it, sometimes in the same sense, and sometimes in a contrary one ; so that, if it be supposed, for example, that the air is heated about the hygrometer, on one part, this air, whose dissolving power with regard to the water will be augmented, will take away from the hair a portion of the water which it had imbibed, thus tending to shorten the hair ; while, on the other part, the heat, by penetrating it, will tend, though much more feebly, to lengthen it ; and hence

the total effect will be found to consist of two partial and contrary effects, the one hygrometric, the other pyrometric. In observations which require a certain precision, it is therefore necessary to consult the thermometer at the same time with the hygrometer; and on this account, the inventor has constructed, from observation, a table of correction, which will put it in the power of philosophers always to ascertain the degree of humidity of the air, from the effect produced by the heat.

HYGROMETER, (DE LUC's,) fig. 1, plate V.—De Luc employed for the construction of his hygrometer, a thin slip of whalebone, which performs the same office as the hair in the hygrometer of Saussure. He kept this whalebone bent by means of a spring, the action of which he preferred to that of a weight: he determined the degree of extreme humidity, by immersing the slip of whalebone entirely under water; and to fix the opposite limit, which is that of extreme dryness, he made use of quick lime, which he enclosed with the hygrometer under a glass bell. The choice of lime is founded on this, that the calcination of it having produced a higher degree of dryness, if it be afterwards left to cool, so far that it may be placed without inconvenience under the glass bell destined for the experiment, it will be still found, as to sense, in the same state of dryness, since it is very slow in acquiring humidity; and thus all its absorbent power will be employed to dry up, by little and little, the air contained under the receiver, and to make the hygrometer itself pass to a state which approaches the nearest possible to extreme dryness.

The design exhibited fig. 1, plate V., shows De Luc's

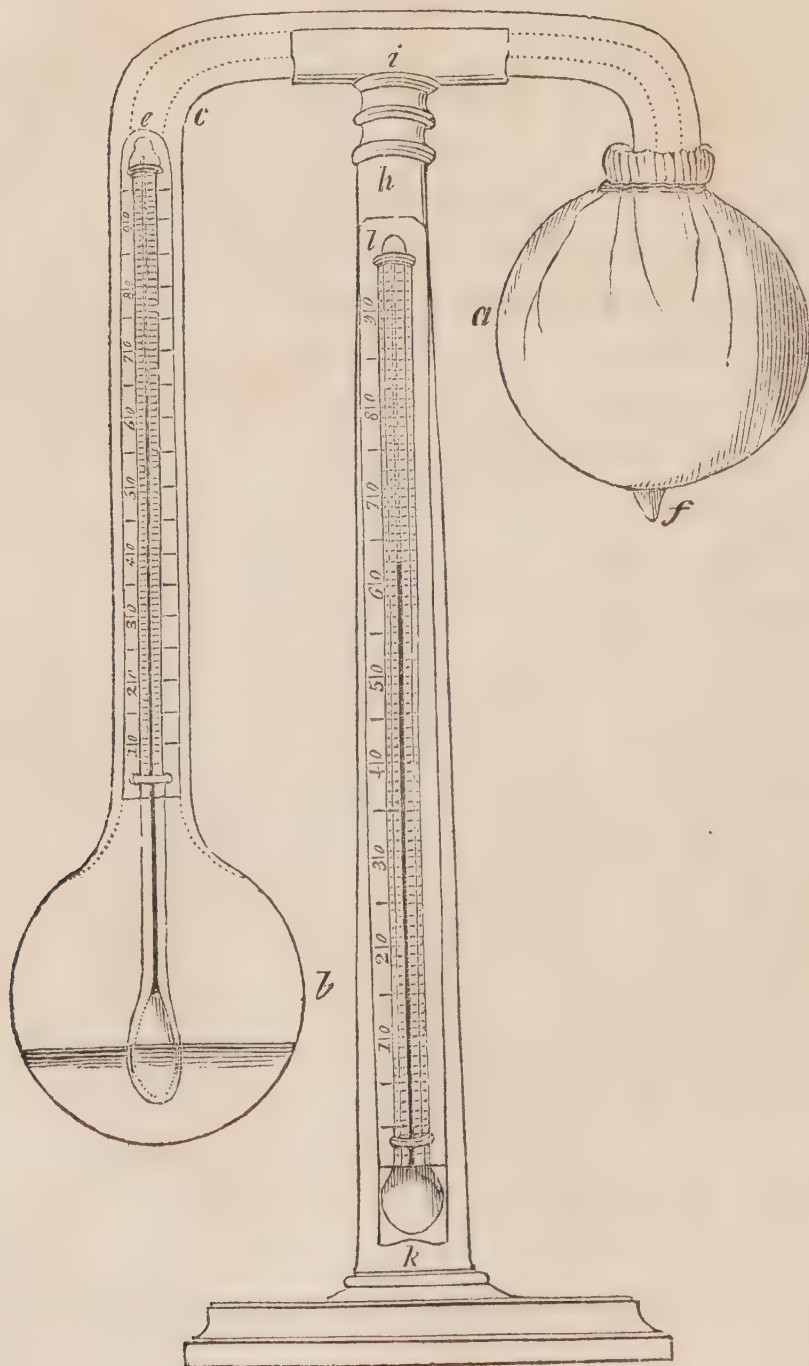
hygrometer as now constructed for common use; it is made of various dimensions, but the figure is but one half the size of the instrument. The slip of whale-bone is represented by *a, b*, one end is fixed to a bar, which is moved by a screw for adjusting first the index on the dial ring *x*.

HYGROMETER, (DANIELL'S).—This hygrometer excels all others in sensibility and accuracy; it is not liable to be out of order, its application requires no skill, and it is the best weather glass that has been contrived. We are indebted to Mr. Daniell for some curious and highly important facts with regard to the application of this new instrument; he has amply shewn,* that by the help of this hygrometer, when associated with the action of the barometer and the thermometer, we have reason to hope to unravel, with more or less success, the complication of different causes which influence the variations of the atmosphere; for it is only by the aid of a long series of observations, made conjointly by these instruments, together with all the indications which are deduced from the state of the heavens, that we can obtain such data as will enable us to prognosticate, with great probability, meteorological changes, and to arrive at a plausible theory upon this object, so interesting, and so naturally calculated to excite our curiosity. We exist in a continual dependence upon the atmosphere, and upon the timely alterations of serene and rainy days, for the labours of agriculture, for our voyages, for our various enterprises, and even for our amusements and pleasures. Mr. Daniell's hygrometer is well calculated to blend the

* Journal of Science and Art, Vol. 9. No. XVII.

useful with the agreeable in an obscure art which may put it in our power to take precautions against what we apprehend and to enjoy by well founded anticipation, that which excites our hopes.

The subjoined figure exhibits a sketch of Mr. Daniell's new hygrometer.



A and *b* are two thin glass balls of $1\frac{1}{4}$ inch in diameter, connected together by a tube, having a bore of about $\frac{1}{8}$ th of an inch. The tube is bent at right angles over the two balls, and the arm *b, c*, contains a small thermometer, *d, e*, whose bulb, which should be of a lengthened form, descends into the ball *b*. This ball, having been about two-thirds filled with ether, is heated over a lamp till the fluid boils, and the vapour issues from the capillary tube *f*, which terminates the ball *a*. The vapour having expelled the air from both balls, the capillary tube *f* is closed hermetically by the flame of a lamp. This process is well known to those who are accustomed to blow glass, and may have been known to have succeeded, after the tube has become cool, by reversing the instrument and taking one of the balls in the hand, the heat of which will drive all the ether into the other ball, and cause it to boil rapidly. The ball, *a*, is now to be covered with a piece of muslin. The stand *g, h*, is of brass, and the transverse socket *i*, is made to hold the glass tube, in the manner of a spring, allowing it to turn and be taken out with little difficulty. A small thermometer, *k, l*, is inserted into the pillar of the stand.

The manner of using the instrument is this: After having driven all the ether into the ball *b*, by the heat of the hand, it is to be placed in an open window, or out of doors, with the ball *b* so situated as that the surface of the liquid may be upon a level with the eye. A few drops of ether are then to be poured upon the covered ball. Evaporation immediately takes place, which producing cold upon the ball *a*, causes a rapid and continuous condensation of the ethereal vapour in the interior of the instrument. The consequent evaporation from the included ether produces cold in the ball *b*, the degree of which is measured by the thermometer, *d, e*. This action is almost instantaneous.

The thermometer begins to fall in two seconds after the ether has been dropped. A depression of 30 degrees is easily produced, and sometimes the ether boils, and the thermometer falls below 0° of Fahrenheit's scale. The artificial cold thus produced causes a condensation of the atmospheric vapour upon the ball *b*, which first makes its appearance in a thin ring of dew coincident with the surface of the ether. The degree at which this takes place is to be carefully noted. A little practice may be necessary to seize the exact moment of the first deposition, but certainty is very soon acquired. It is advisable to have some dark object behind the instrument, such as a house or a tree, as the cloud is not so soon perceived against an open horizon. The depression of temperature is first produced at the surface of the liquid where evaporation takes place, and the currents which immediately ensue to restore the equilibrium, are very perceptible. The bulb of the thermometer *d e* is not quite immersed in the ether, that the line of greatest cold may pass through it. The greatest difference that Mr. Daniell has observed in the course of four month's daily experiments between the external thermometer *k l*, and the internal one *e d*, at the moment of precipitation in the natural state of the atmosphere, was 20 degrees. In very damp weather the ether should be slowly dropped upon the ball, otherwise the descent of the thermometer is so rapid as to render it impossible to be certain of the degree. In dry weather, on the contrary, the ball requires to be well wetted more than once, to produce the requisite degree of cold. It is almost superfluous to observe, that care should be taken not to permit the breath to affect the glass. With these precautions the observation is simple, easy, and certain.

When the instrument is required to act merely as a weather-glass, to predict the greater or less probability of

rain, &c. which is the commonest use to which it can be applied, the difference between the constituent temperature of the vapour, and that of the air, is all that is necessary to be known. The probability of rain or other precipitation of moisture from the atmosphere, is in an inverse proportion to this difference. As a weather-glass, this hygrometer* is more to be depended upon than any instrument that has yet been proposed.

By combining the rise and fall of the barometer with the effects of this instrument, we learn to modify their results, and by so doing can hardly be deceived in the weather for many hours in advance. The indications are to be corrected according to circumstances in the following manner :—In summer time, when the diurnal variations of temperature are great, regard is to be had to the time of day at which the experiment is made. In the morning, supposing the difference between the temperature of the air and the constituent temperature of the vapour to be small, it is to be recollected, that the accession of heat during the day is great, and that the difference will therefore probably increase. If the point of condensation should at the same time be lowered, it is an indication of very fine weather. If, on the contrary, the heat of both should increase with the day in nearly equal progression, rain will almost infallibly follow, as the heat of the air falls with the setting sun. In showery weather the indications of this instrument vary rapidly three or four degrees, and a person making observations at short intervals of time, may easily predict the approach of a storm.

Fogs also, and mists, must be taken into consideration. They produce the same effect upon the instrument as the

* See the *Journal of Science and Art*, Vol 9; No. XVII.

greater precipitations of rain. A change from fine weather to rain is more quickly perceptible in low situations than one from wet to fine, for the effect of a shower lasts rather longer than the state of the atmosphere in higher regions would warrant, on account of the damp exhalations from the moistened ground.

In cases of mist, fog, and cloud, the instrument will sometimes exhibit a different kind of action. If it be brought from an atmosphere of a higher temperature into one of a lower degree, in which condensed aqueous particles are floating, the mist will begin to form upon the ball at a temperature several degrees higher than that of the air. The difference, Mr. Daniell believes, is proportionate to the density of the cloud or mist; but, this philosopher says, "I speak with diffidence upon this point, as I have not had sufficient opportunities of verifying it by experiment. I have sometimes thought, that I have perceived a difference in this respect, in different modifications of the cloud, but this must be referred to future more extended observations. This action upon floating water does not at all interfere with it as measuring the force and quantity of vapour, for in all such cases the full saturation of the atmospheric temperature must have place, and consequently the temperature of the vapour must be coincident with that of the air."

Although the hygrometer we are now describing excels all others in sensibility, and accuracy with which it marks the comparative degrees of moisture and dryness in the atmosphere, and, by exhibiting them in degrees of the thermometer, refers them to a known standard of comparison, and thus speaks in a language which every body understands; yet, Mr. Daniell observes, it is not upon this alone that he ventures to found its claims of superiority. The great merit of this instrument

consists in indicating with ease and precision the positive weight of aqueous gas diffused through any given portion of space, and the force and elasticity of vapour, as measured by the column of mercury which it is capable of supporting. The means of finding these with ease and precision are furnished by the subjoined Table, upon the construction of which it will be necessary to make a few remarks:

TABLE I.

Shewing the Force, Density, and Expansion, of Aqueous Vapour, at different Degrees of Temperature, from 0° to 92° Fahr.

Temp.	Force.	Weight of a Cubic Foot.	Expan- sion.	Temp.	Force.	Weight of a Cubic Foot.	Expan- sion.
Fahr.	Inches of Mercury.	Grains.		Fahr.	Inches of Mercury.	Grains.	
0 °	0.064	0.789	1.000	22	0.139	1.642	1.045
1	0.066	0.812	1.002	23	0.144	1.698	1.047
2	0.068	0.835	1.004	24	0.150	1.763	1.050
3	0.071	0.870	1.006	25	0.156	1.831	1.052
4	0.074	0.906	1.008	26	0.162	1.897	1.054
5	0.076	0.928	1.000	27	0.168	1.959	1.056
6	0.079	0.963	1.012	28	0.174	2.030	1.058
7	0.0 2	0.997	1.014	29	0.180	2.096	1.060
8	0.085	1.032	1.016	30	0.186	2.162	1.062
9	0.087	1.054	1.018	31	0.193	2.240	1.064
10	0.090	1.089	1.020	32	0.200	2.317	1.066
11	0.093	1.123	1.022	33	0.207	2.393	1.068
12	0.096	1.156	1.024	34	0.214	2.438	1.070
13	0.100	1.202	1.027	35	0.221	2.545	1.072
14	0.104	1.247	1.029	36	0.229	2.629	1.075
15	0.108	1.292	1.031	37	0.237	2.717	1.077
16	0.112	1.337	1.033	38	0.245	2.803	1.079
17	0.116	1.411	1.035	39	0.254	2.900	1.081
18	0.120	1.428	1.037	40	0.263	2.999	1.083
19	0.124	1.474	1.039	41	0.273	3.106	1.085
20	0.129	1.529	1.041	42	0.283	3.214	1.087
21	0.134	1.586	10.43	43	0.294	3.326	1.089

TABLE I. *Continued.*

Temp.	Force.	Weight of a Cubic Foot.	Expan- sion.	Temp.	Force.	Weight of a Cubic Foot.	Expan- sion.
Fahr.	Inches of Mercury.	Grains.		Fahr.	Inches of Mercury.	Grains.	
44	0.305	3.452	1.091	69	0.698	7.541	1.143
45	0.316	3.570	1.093	70	0.721	7.776	1.145
46	0.328	3.699	1.095	71	0.745	8.027	1.147
47	0.339	3.815	1.097	72	0.770	8.270	1.150
48	0.351	3.940	1.100	73	0.796	8.533	1.152
49	0.363	4.068	1.102	74	0.823	8.807	1.154
50	0.375	4.195	1.104	75	0.851	9.091	1.156
51	0.388	4.330	1.106	76	0.880	9.385	1.158
52	0.401	4.468	1.108	77	0.910	9.688	1.160
53	0.415	4.616	1.110	78	0.940	9.992	1.162
54	0.429	4.770	1.112	79	0.971	10.292	1.164
55	0.443	4.910	1.114	80	1.000	10.591	1.166
56	0.458	5.068	1.116	81	1.040	10.993	1.168
57	0.474	5.235	1.118	82	1.070	11.293	1.170
58	0.490	5.402	1.120	83	1.100	11.590	1.172
59	0.507	5.507	1.124	84	1.140	11.981	1.175
60	0.524	5.761	1.125	85	1.170	12.252	1.177
61	0.542	5.950	1.127	86	1.210	12.681	1.179
62	0.560	5.126	1.129	87	1.240	12.966	1.181
63	0.578	6.310	1.131	88	1.280	13.368	1.183
64	0.597	6.506	1.133	89	1.329	13.756	1.185
65	0.616	6.614	1.135	90	1.360	14.150	1.187
66	0.635	6.912	1.137	91	1.400	14.542	1.189
67	0.655	7.013	1.139	92	1.440	14.931	1.191
68	0.676	7.316	1.141				
				212	30.000	257.119	1.44

These tables are constructed upon Dalton's experiments on the force of vapour from water. The second column of the table exhibits the force of aqueous vapour, in inches of mercury at the temperature opposed to it in the first column. Upon these two *data*, namely, the force and temperature of the vapour, are founded the calculations which have furnished Mr. Daniell with the series of the third column, which contains the weight in grains of a

cubic foot of the vapour at the corresponding temperature and pressure. The method of proceeding is this: Steam at 212° , and under a pressure of 30 inches of mercury, is, as nearly as possible, 1700 times lighter than an equal bulk of water. A cubic foot of water at its maximum of density, weighs 437102.4946 grains. The weight, therefore, of a cubic foot of steam at the above temperature and pressure, is $\frac{437102.4946}{1700}$ or 257.1191 grains. From hence we may find the weight of an equal bulk of vapour of the same temperature, under any other given pressure, suppose 0.524: for the volume being in inverse proportion to the pressure

$$\begin{array}{cccc} \text{Ins.} & \text{Ins.} & \text{Grs.} & \text{Grs.} \\ 30. : 0.524 : : 257.119 : 4.491 \end{array}$$

the weight required.

Having now obtained the weight of a cubic foot of vapour, at a pressure of 0.524, and at a temperature of 212° , we may proceed to find its weight under the same pressure, at any other temperature, suppose 60° . The gases, it will be remembered, expand $\frac{1}{480}$ part of their volume for every accession of heat, equal to 1° of Fahrenheit's scale; therefore reckoning as unity a volume of gas at 0° , its volume at 60° is to its volume at 212° as $1 + \frac{60}{480}$ is to $1 + \frac{212}{480}$, or :: 1.125 : 1.441, therefore the density and weight being an inverse proportion to the volume

$$\begin{array}{cccc} \text{Ins.} & \text{Ins.} & \text{Grs.} & \text{Grs.} \\ 1.125 : 1.441 : : 4.491 : 5.628 \end{array}$$

the weight of a cubic foot of vapour at the temperature of 60° , and a pressure of 0.524 inches.

It must be further remembered, that it has been proved by Mr. Dalton, that as much vapour of determined temperature is formed in a given bulk of air, as in a vacuum of equal space; therefore the above result gives the weight of vapour, which can exist in a cubic foot of the

air at the temperature of 60° . The fourth column of the table contains the proportionate expansion for the corresponding degrees.

The calculations for these several series have been made to the third place of decimals, which will be sufficiently accurate for all common purposes. The manner of using the table will be best understood from an example.

Let the temperature of the atmosphere be 70° ; and the point of condensation, as found by the hygrometer, 55° ; the pressure of the vapour, under these circumstances, is immediately found opposite to the degree of its constituent heat 55° 0.443. To find its weight, we proceed thus:—supposing as much as possible to exist in the space of a cubic foot, its weight would be found upon the same line as its pressure, 4.910 grs. But its bulk is expanded by the existing temperature of the air; therefore we must seek in the fourth column for the degree of expansion, at 55° 1.114, and at 70° 1.145, and apply the correction thus:—

Bulk at 70° .	Bulk at 55° .	Grs.	Grs.
1.145	: 1.114	: :	4.910 : 4.777

the weight required.

Now the state of the atmosphere, assumed above, would constitute fine weather, and one of two things, or a modification of both, must happen before any precipitation of water could take place; either the temperature of the air must fall below 55° , or the quantity of vapour must increase to 7.776 grs. in the cubic foot, the maximum quantity that could exist at 70° , or the point of condensation might become intermediate, by a corresponding rise and fall of the two.

In the first case, the precipitation would probably be only slight and transitory, such as mist, fog, or small

rain. In the second case, it would assume the form of hard rain and storms; while in the third, some conjecture might be formed of its probable duration and quantity, according as one or other of its causes prevailed.

But the hygrometer can be made to measure, not only the quantity and force of vapour existing at any time in the air, but also it may be applied to indicate the force and quantity of evaporation. Mr. Dalton, in the course of that important train of investigation to which we have before had occasion to refer, ascertained that the quantity of water evaporated in a given time, bore an exact proportion to the force of vapour at the same temperature. The atmosphere obstructs its diffusion, which would otherwise be almost instantaneous, as in vacuo, but this obstruction is overcome in proportion to the force of the vapour. The obstruction, however, does not arise from the weight of the atmosphere, for that would prevent any vapour from arising under 212° ; but, as Mr. Dalton observes, is caused by the *vis inertiae* of the particles of air, and is similar to that which a stream of water meets with in descending amongst pebbles. In ascertaining this point at ordinary atmospheric temperatures, regard must be had to the force of vapour already existing in the air. For instance, if water of 59° were the subject, the force of vapour of that temperature is $\frac{1}{60}$ of the force at 212° , and one might expect the quantity of evaporation to be $\frac{1}{60}$ also; but if it should happen, that an aqueous atmosphere to that amount does already exist, the evaporation, instead of being $\frac{1}{60}$ of that from boiling water, would be nothing at all. On the other hand, if the aqueous atmosphere were less than that, suppose half of it, then the effective evaporating force would be $\frac{1}{120}$ of that from boiling water; in short, the evaporating force must be universally equal to that of the temperature of the water, diminished by that already existing in the atmosphere.

But the air, by its mechanical action, has another influence upon the rate of evaporation. When calm and still, it merely obstructs the process; but when in motion, it increases its effect in direct proportion to its velocity, by removing the vapour as it forms. Mr. Dalton fixes the extremes that are likely to occur in ordinary circumstances at 120 and 189grs. per minute, from a vessel of six inches diameter, at a temperature of 212° .

Upon these data, he has constructed the following

TABLE II.

Shewing the Force of Vapour, and the full evaporating Force of every Degree of Temperature, from 20° to 85° , expressed in Grains of Water that would be raised per Minute from a Vessel of six Inches in Diameter, supposing there were no Vapour already in the Atmosphere.

Temp.	Force of Vapour.	Evaporating Force in Grains.			Temp.	Force of Vapour.	Evaporating Force in Grains.		
212.	30.	120.	154.	189.	212.	30.	120.	154.	189.
20	0.129	0.52	0.67	0.82	34	0.214	0.86	1.11	1.35
21	0.134	0.54	0.69	0.85	35	0.221	0.90	1.14	1.39
22	0.139	0.56	0.71	0.88	36	0.229	0.92	1.18	1.45
23	0.144	0.58	0.73	0.91	37	0.237	0.95	1.22	1.49
24	0.150	0.60	0.77	0.94	38	0.254	0.98	1.26	1.54
25	0.156	0.62	0.79	0.97	39	0.245	1.02	1.31	1.60
26	0.162	0.65	0.82	1.02	40	0.263	1.05	1.35	1.65
27	0.168	0.67	0.86	1.05	41	0.273	1.09	1.40	1.71
28	0.174	0.70	0.90	1.10	42	0.283	1.13	1.45	1.78
29	0.180	0.72	0.93	1.13	43	0.294	1.18	1.51	1.85
30	0.186	0.74	0.95	1.17	44	0.305	1.22	1.57	1.92
31	0.193	0.77	0.99	1.21	45	0.316	1.26	1.62	1.99
32	0.200	0.80	1.03	1.26	46	0.327	1.31	1.68	2.06
33	0.207	0.83	1.07	1.30	47	0.339	1.36	1.75	2.13

TABLE II. *Continued.*

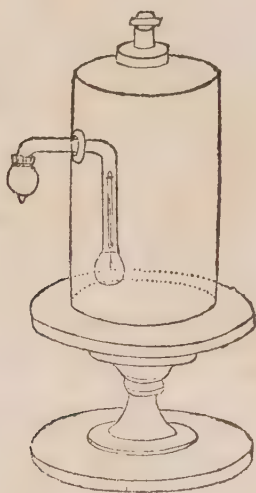
Temp.	Force of Vapour.	Evaporating Force in Grains.			Temp.	Force of Vapour.	Evaporating Force in Grains.		
		120.	154.	189.			120.	154.	189.
212.	30.				212.	30.			
48	0.351	1.40	1.80	2.20	67	0.655	2.62	3.87	4.12
49	0.363	1.45	1.86	2.28	68	0.676	2.70	3.47	4.24
50	0.375	1.50	1.92	2.36	69	0.698	2.79	3.59	4.38
51	0.388	1.55	1.99	2.44	70	0.721	2.88	3.70	4.53
52	0.401	1.60	2.06	2.51	71	0.745	2.98	3.83	4.68
53	0.415	1.66	2.13	2.61	72	0.770	3.08	3.96	4.84
54	0.429	1.71	2.20	2.69	73	0.796	3.18	4.09	5.00
55	0.443	1.77	2.28	2.78	74	0.823	3.29	4.23	5.17
56	0.458	1.83	2.35	2.88	75	0.851	3.40	4.37	5.34
57	0.474	1.90	2.43	2.98	76	0.880	3.52	4.52	5.53
58	0.490	1.96	2.52	3.08	77	0.910	3.65	4.68	5.72
59	0.507	2.03	2.61	3.19	78	0.940	3.76	4.83	5.91
60	0.524	2.10	2.70	3.30	79	0.971	3.88	4.99	6.10
61	0.542	2.17	2.79	3.41	80	1.000	4.00	5.14	6.29
62	0.560	2.24	2.88	3.52	81	1.04	4.16	5.35	6.54
63	0.578	2.31	2.98	3.63	82	1.07	4.28	5.50	6.73
64	0.597	2.39	3.07	3.76	83	1.10	4.40	5.66	6.91
65	0.616	2.46	3.16	3.87	84	1.14	4.56	5.86	7.17
66	0.635	2.54	3.27	3.99	85	1.17	4.68	6.07	7.46

The first column contains the degrees of temperature; the second the corresponding force of vapour; the third the amount of evaporation per minute, from a vessel of six inches diameter, in calm weather; the fourth the amount in a moderate breeze; and the fifth in a high wind.

The use of this table as applied to Mr. Daniell's hygrometer is this: *let it be required to know the force of evaporation at the existing state of the atmosphere. Find the point of condensation by the instrument as before directed; subtract the grains opposite that temperature, either in the third, fourth, or fifth columns, according to the state of the wind, from the grains opposite to the temperature of the air in the same column,*

and the remainder will be the quantity evaporated in a minute, from a vessel of six inches diameter under the given circumstances. For example;—let the point of condensation be 52° , the temperature of the air 65° , with a moderate breeze. The number opposite 52° in the fourth column is 2.06, and that opposite 65° is 3.16; the difference 1.1 grain, is the evaporation per minute.

We shall now proceed to describe the manner of applying the hygrometer to artificial atmospheres, and to detail some experiments with it, detached from the preceding series. The subjoined figure represents a bell-glass, prepared for this purpose.



A hole is drilled in its side, through which the tube, proceeding from the ball placed under it, containing the thermometer, is passed, and welded with the tube proceeding from the other ball on its exterior side, by means of a lamp; the stem is then secured in the side of the glass by means of cement, and the ether boiled, and the capillary opening secured as before directed. The exterior ball is then to be covered with muslin. In this way the evaporation from the latter produces a corresponding degree of cold upon

the ball under the bell-glass, and will measure the quantity of vapour included, by the precipitation which may readily be marked. The bell-glass may be secured by grinding, and other well known means, from any communication with the exterior air.

The hygrometric properties of any substance may thus be easily measured, by placing it under the receiver, and marking the absorption of the vapour.

The last application of the hygrometer, which we shall point out, is perhaps of superior importance to any of those which we have been considering. We mean the correction which it affords to barometrical measurements. The principle upon which the barometer is at present applied to the determination of heights, is the gradation of the density of the atmosphere, considered as a homogeneous fluid of uniform composition. The only correction at present applied, is an allowance for the disturbing influence of heat by the expansion of the air, and consequent augmentation of the elevation due to a given difference of atmospheric pressure. But the atmosphere is not, in fact, of uniform composition; the quantity of aqueous vapour, one of its component parts, varies almost every hour of the day. It is subject to sudden increase, and as sudden diminution: and in its ascent to higher regions, follows a very different law from that of the permanent elastic fluids. The barometer measures the total pressure of the compound atmosphere, the hygrometer furnishes us with the means of estimating the insulated pressure of that portion of it, which is fluctuating in quantity, and uncertain in composition; by deducting the latter from the former, we bestow upon the problem the necessary condition of its assumed simplicity. In low latitudes this correction is of most particular importance, as the pressure and quantity of the vapour is in some proportion to the heat.

For example, Capt. Webb, in his Memoir upon the Measurement of the Himàlaya Mountains,* informs us, that he computed the elevation of a number of stations upon that lofty range, from the observation of a column of mercury, compared with the mean height of the barometer at Calcutta in the same season. Now the thermometer, in the latitude of the latter place, generally ranges throughout the year between 75° and 95° , and often rises to 100° , and sometimes to 110° . We shall, therefore, be probably under the mark in assuming the temperature of Calcutta, during Captain Webb's observations, at 80° . The summits of the Himàlaya mountains are above the limits of perpetual congelation; therefore, we cannot be much in error in fixing the temperature of these higher stations at 32° . We will next suppose that the air at Calcutta was not saturated with moisture, but that the point of condensation was 10° below the temperature of the air, while, on the mountain, it was at its highest limit. The column of mercury which the former would support would be 0.721 in., while that which would counterbalance the latter, would only be 0.200 in., making a difference of 0.521 in., to be deducted from the height of the barometer at the lower station, and amounting to an error of 468 feet in the estimated height of the upper. This, of course, as far as regards the Himàlaya measurements, is a very rough calculation, and the amount of the error is probably below the truth; it will, however, sufficiently demonstrate the nature and importance of the correction. In higher latitudes, and in the winter season, the state of the vapour may more safely be disregarded, for its pressure increases much more rapidly in the higher part of the thermometric scale for every degree of temperature, than it does in the

* Journal of the Royal Institution, Vol. vi. p. 55.

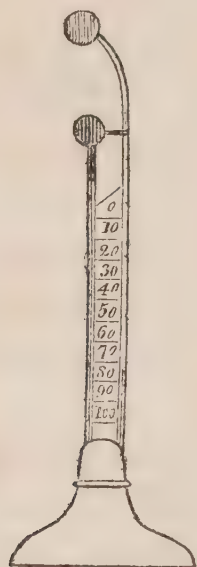
lower ; its influence, however, under all circumstances, is sufficiently great to make it of consequence, when any thing like accuracy is required.

We shall now conclude this abstract of Mr. Daniell's paper. No one, says this philosopher, can be more aware than myself of the incomplete state in which I have presumed to bring forward my observations. More time, and better opportunities, were required to attain that accuracy which is so desirable in experimental inquiries. London, moreover, is perhaps the worst place in the world for meteorological pursuits. Observations upon clouds, dew, and winds are almost precluded, and any comparison of heights is very limited indeed. Knowing, however, that the great value of the instrument which I have contrived, must be derived from the number, extent, and comparison of the experiments to be performed with it, by different observers, in different situations, I have thought it more for the advantage of science to bring it forward at once, trusting to the candour of the learned to allow of the validity of the excuse.

HYGROMETER, (LESLIE'S.)—The ball of the differential thermometer, (fig. 1, plate XIII.,) which contains the supply of coloured liquid, or of the photometer being covered with several coats of cambric or tissue paper, and wetted with pure water, forms Leslie's Hygrometer, it will mark, by the descent of the column in the opposite stem, the constant diminution of temperature which is caused by evaporation from that humid surface, and it must consequently express the relative dryness of the ambient air. In a very short space, seldom indeed exceeding two minutes, the full effect is produced; and under the same circumstances, it will continue unaltered, till the whole of the moisture has exhaled. To exclude

entirely the mixture of photometrical influence, or prevent any derangement which the action of light might otherwise occasion, the opposite balls are made to exhibit nearly the same colour and opacity, the naked one being blown of green and blue glass, or the papered one besides covered with a bit of thin silk, of rather a light shade, so as to take a deeper tint when moistened.

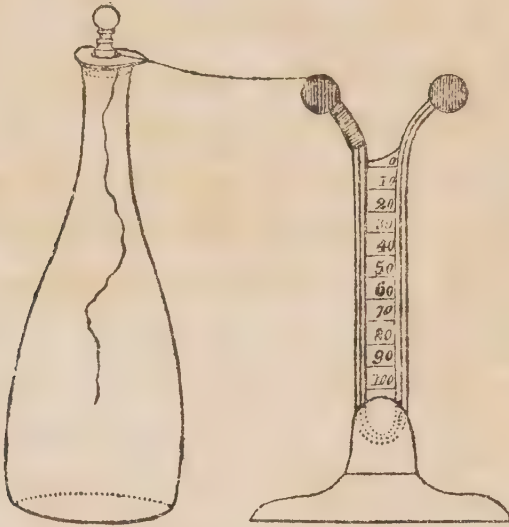
Leslie's hygrometer has, like his photometer, two different forms; the one portable, and the other stationary. The former, having its balls in the same perpendicular line as here represented; it is protected by a case of wood



or ivory, and fitted for carrying in the pocket; two or three drops of pure water from the tip of a quill or a hair pencil being applied to the surface of the covered ball, and the instrument held in a vertical position as often as it is used.

The latter form is calculated for somewhat greater accuracy than the other, since its balls, though bent opposite ways, are on the same level. In this construction of the instrument, the covered ball, after being once wetted, is kept constantly moist, by means of some fibres

of floss-silk passing close over it, and immersed, at the distance of a few inches in a tall glass decanter full of water, with a stopper which leaves open a small projecting lip.



The capillary attraction of these filaments conveys the liquid to the surface of the humid ball, as fast as it wastes by evaporation; but to insure their regular action, the silk should be previously soaked in hot water, to extract any gum that may adhere to it, and the mouth of the decanter should stand a little higher than the balls of the hygrometer. When thus arranged, the hygrometer will, without any help, perform accurately for weeks or even months; and after the silky filaments have become choked with dust, their activity may be again restored by washing them carefully with a fine wet brush.

The condition of the atmosphere with respect to dryness is extremely variable. In our climate, says Professor Leslie, the hygrometer will, during winter, mark from 5 to 25 degrees; but, in the summer months, it will generally range between 15 and 55 degrees, and may even rise, on some particular days, as high as 80 or 90 degrees. In thick fogs, the instrument stands almost at the beginning

of the scale ; it commonly falls before rain, and remains low during wet weather ; but it mounts powerfully in continued tracts of clear and warm weather. The greatest dryness yet noticed was at Paris, in the month of September, when it reached to 120 degrees. But for want of observations, we are totally unacquainted with the real state of the air in the remote and tropical climates.

When the indication of the hygrometer does not exceed 15 degrees, we are directed by our feelings to call the air damp ; from 30 to 40 degrees we begin to reckon it dry ; from 50 to 60 degrees we should account it very dry, and from 70 degrees upwards we might consider it as intensely dry. A room is not comfortable, or perhaps wholesome, if it has less than 30 degrees of dryness ; but the atmosphere of a warm occupied apartment will commonly produce an effect of upwards of 50 degrees.

But this hygrometer will perform its office even if it be exposed to frost. The moisture spread over the surface and imbibed into the coat of the papered ball, will first cool a few degrees below the freezing point, and then congeal quickly into a solid compound mass. The moment in which congelation begins, a portion of heat liberated in that act brings the ball back to the temperature of freezing, and the coloured liquor, in proportion to the coldness of the external air, starts up in the opposite stem, where it remains at the same height, till the process of consolidation is completed. After the icy crust has been formed, evaporation again goes regularly forward ; and if new portions of water be applied, the ice will, from the union of those repeated films, acquire a thickness sufficient to last for several days. The temperature of the frozen coat becomes lowered in proportion to the dryness of the atmosphere. The measure of heat deposited on the chill surface by the contact of the ambient air is then counter-

balanced by the two distinct, though conjoined measures of heat, abstracted in the successive acts of converting the exterior film of ice into water and this water into steam; which transformations that minute portion must undergo before it can unite with its gaseous solvent. But the heat required for the melting of ice being about the seventh part of what is consumed in the vaporization of water, it follows that the hygrometer, when the surface of its sentient ball has become frozen, will, in like circumstances, sink more than before by one degree in seven. This inference is entirely confirmed by observation. Suppose, in frosty weather, the hygrometer, placed on the outside of the window, to stand at 28 degrees; it may continue for some considerable time at that point, until the congelation of its humidity commences: but after this change has been effected, and the equilibrium again restored, the instrument will now mark thirty-two degrees.

The theory of Leslie's hygrometer will enable us to determine not only the relative, but even the absolute dryness of the air or the quantity of moisture which it can absorb, by comparing the capacity of that solvent with the measure of heat required to convert a given portion of water into steam. To discover the capacity of air, is however a problem of great difficulty, and it has not been yet ascertained with much precision. Professor Leslie thinks that it is generally estimated by far too high; and from several concurring observations, he reckons the capacity of air to be only three eighth parts of that of water. But 600 centigrade degrees, or 6000 on the millesimal scale, being consumed in the vaporization of water, this measure of heat would prove sufficient to raise an equal mass of air 16,000 millesimal degrees, or those 6000 degrees augmented in the ratio of 8 to 3.

Now, at the state of equipoise, the quantity of heat that each portion of the aërial medium deposits in touching the chill exhaling surface, or what answers to the depression of temperature which it suffers from this contact, must, as we have seen, be exactly equal to the opposite measure of heat abstracted by it in dissolving its corresponding share of moisture. Wherefore, at the temperature of the wet ball, atmospheric air would take up moisture amounting to the 16,000th part of its weight, for each degree marked by the hygrometer. Thus supposing the hygrometer to mark 50 degrees, the air would then require humidity equal to the 320th part of its weight, for saturation at its reduced temperature. When the papered ball of the hygrometer is frozen, the degrees on this instrument must have their value increased by one-seventh, so that each of them will now correspond to an absorption of moisture equal to the 14,000th part of the weight of the air.

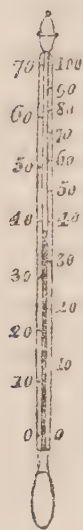
But the value of those degrees becomes augmented in a much higher proportion, if the hygrometer be immersed in hydrogen gas. Since this very dilute medium has ten times the capacity of common air, the quantity of heat which, under similar circumstances, it will deposite on the evaporating surface, must likewise, from the same principle of mutual balance, be tenfold greater, and consequently each hygrometric degree will indicate an absorption of moisture equal in weight to the 600th part of the solvent. The energy of hydrogen gas is therefore not less remarkable in dissolving moisture than in containing heat.

Professor Leslie observes, that if a large receiver, having a delicate hygrometer suspended within it, be placed on a brass plate and over a metal cup containing some water, the included air will, from the solution of the moisture,

become gradually damper, and this progressive change is marked by the instrument. Yet the mass of air will never reach its term of absolute humidity, and before the hygrometer points at 5 degrees, the inside of the receiver appears covered with dew. While the humifying process therefore still goes on, the close attraction of the glass continually robs the contiguous air of a portion of its moisture; so that a kind of perpetual distillation is maintained through the aërial medium; the vapour successively formed, being again condensed on the vitreous surface. But if, instead of the receiver, there be substituted a vessel formed of polished metal, the confined air will pass through every possible degree of humidity, and the hygrometer will, after some interval, arrive at the beginning of its scale.

HYGROSCOPE. (LESLIE'S). Professor Leslie has lately revived a method of measuring the expansion of absorbent cohesive substances, by their enlargement of capacity when disposed into a shell; and has carried the hygroscope thus formed to as high a state of improvement as perhaps such an imperfect instrument will admit.* A piece of fine grained ivory, about an inch and quarter in length, is turned into an elongated spheroid, as thin as possible, weighing only eight or ten grains, but capable of containing, at its greatest expansion, about 300 grains of mercury; and the upper end, which is adapted to the body by means of a delicate screw, has a slender tube inserted, six or eight inches long, and with a bore of nearly the 15th part of an inch in diameter.

* Leslie on Heat and Moisture, page 108.



The instrument being now fitted together, its elliptical shell is dipped into distilled water, or lapped round with a wet bit of cambric, and after a considerable interval of time, filled with mercury to some convenient point near the bottom of the tube, where is fixed the beginning of the scale. The divisions themselves are ascertained, by distinguishing the tube into spaces which correspond each of them to the thousandth part of the entire cavity, and equal to the measure of about three-tenths of a grain of mercury. The ordinary range of the scale will include 70 of these divisions. To the upper end of the tube, is adapted a small ivory cap, which allows the penetration of air, but prevents the escape of the mercury, and thereby renders the instrument quite portable.

This hygroscope is largely, though rather slowly, affected by any change in the humidity of the ambient medium. As the air becomes drier, it attracts a portion of moisture from the shell or bulb of ivory, which, suffering in consequence a contraction, squeezes its contained mercury so much higher in the tube. But if, on the contrary, the air should incline more to dampness, the thin

bulb will imbibe moisture and swell proportionally, allowing the quicksilver to subside towards its enlarged cavity. These variations, however, are very far from corresponding with the real measures of atmospheric dryness or humidity. Near the point of extreme dampness, the alterations of the hygroscope are much augmented; but they diminish rapidly, as the mercury approaches the upper part of the scale. The contraction of the ivory answering to an equal rise in the dryness of the air, is six times greater at the beginning of the scale than at the 70th hygroscope division; and seems in general to be inversely as the number of hygrometric degrees, reckoning from 20 below. Professor Leslie has therefore placed another scale along the opposite side of the tube, the space between 0 and 70 of the hygroscope being distinguished into 100 degrees, and corresponding to the unequal portions from the number 20 to 120 on a logarithmic line. This very singular property is more easily conceived from the inspection of the figure. The scale might be safely extended farther, by continuing the logarithmic divisions. Thus, 320 degrees by the hygrometer would answer to 108 of the hygroscope, or to a contraction of 108 parts in a thousand in the capacity of the bulb. But at the dryness of 300, Professor Leslie never found the contraction of the ivory to exceed 105. He likewise formed box-wood into a hygroscope, of the same shape and dimensions; but this absorbent material swells twice as much with moisture as ivory does, and therefore requires its inserted tube to be proportionally longer or wider. The contractions of box are still more unequal than those of ivory. Near the point of extreme humidity, those alterations in the capacity of the bulb seem to be more than twenty times greater than, under like changes, in the condition of the atmosphere, take place towards the upper

part of the scale. The space included between the commencement and the 140th millesimal division of the scale, might hence be marked with 100 hygrometric degrees, corresponding to the decreasing portions of a logarithmic line from five to 105.

In noticing the rapidly declining contractions which ivory and box undergo, Professor Leslie would not be understood, however, to state the quantities with rigorous precision ; he merely considers the numbers given above as very near approximations to the truth. I should be ashamed, says the Professor, to confess how much time I have already consumed in tracing out the law of those contractions. Such experiments are rendered the more tedious, from the protracted action of the hygroscope, which often continues travelling slowly for the space of a quarter or even half an hour. This tardiness is indeed the great defect of all instruments of that nature, and utterly disqualifies them for every sort of delicate observation.

The very large expansions which the hygroscope shows on its approach to extreme humidity, explains in a satisfactory manner the injury which furniture and pieces of cabinet-work sustain from the prevalence of dampness. On the other hand, the slight alteration which the instrument undergoes in a medium of highly dry atmosphere, seems to have led most philosophers to believe that there is an absolute term of dryness, on the distance of which, from the point of extreme moisture, they have generally founded the graduation of the different hygrosopes proposed by them. This opinion, however, is far from being correct, and might give occasion to most erroneous conclusions. No bounds can be set to the actual dryness of the air, or the quantity of moisture which it is capable of holding, and which, by the joint application of heat and

rarefaction to the solvent, may be pushed to almost indefinite extent.

The ivory hygroscope, after being for several hours immersed in air of 150 or 200 degrees of dryness was apt of a sudden to split longitudinally. But if the bulb endured such a range of contraction, it appeared in some instances to take at least *another set*, or to accommodate its constitution, by imperceptible gradations, to the state of the surrounding medium. If this remark were confirmed, it would elucidate finely the atomical system of bodies, and establish the successive limits of corpuscular attraction and repulsion.

But though the bulbous hygroscope is, in extreme cases, liable to much uncertainty and some risk, it may yet be used with visible advantage, in a variety of situations, as an auxiliary merely to the hygrometer. The very sluggishness of the instrument, when the value of its divisions has been once ascertained, fits it so much the better for indicating the mean results. After being long exposed in situations hardly accessible, it may be conveniently transported for inspection before it can suffer any sensible change. The hygroscope could be, therefore, employed with success to discover the degree of humidity which prevails at certain considerable elevations in the atmosphere. It might be likewise used for ascertaining readily the precise condition of various goods and commodities. Thus, if the bulb were introduced, for the space perhaps of half an hour, into a bag of wool, a sack of corn, or a bale of paper, it would, on being withdrawn from their contact, mark the dryness or humidity of those very absorbent substances.

The softer absorbent substances are not only themselves affected by the state of the ambient medium, but are capable, when they expose a broad attractive surface,

of assimilating to their previous condition, air and other gaseous fluids confined over them. Flannel, for instance, which has been intensely dried before a strong fire, will support a remarkable degree of dryness in a close receiver; yet after a few repeated applications, it soon becomes saturated with humidity, and loses its power of absorption. Muriate of lime has a vigorous and extended energy; but the substance which answers best on the whole as an absorbent, and which continues for a long time to attract moisture with almost undiminished force, is the concentrated sulphuric acid. By the action of this material, I am enabled, says Professor Leslie, to maintain, for weeks or even months together, a magazine of dry air, which affords the means of accurately graduating the differential thermometer and its several modifications. But, by exposing, at the same time, under the receiver a surface of water in given proportion to that of the acid, the confined air may easily be reduced to any inferior state of dryness.

INGOTS.—Fused bodies are either suffered to congeal in the melting vessels, or they are poured into the cavity of a warm stone, or in an inverted *metallic cone*, See CASTING CONE, page 11, or *ingots*, fig. 1, plate VIII. In these last the fused metals are suffered to congeal in the shape of flat, or roundish oblong masses, called *pigs*, or of *bars*.

JARS, GRADUATED, fig. 2, plate 1.—To determine the volume of aeriform fluids glass jars divided cubic inches, and subdivided into decimal parts are employed. The contents of these jars should be marked on the outside by means of a diamond, beginning at the top of the jar, when it stands inverted on the shelf of the pneumatic trough.

In many cases jars divided into equal arbitrary parts are useful.

The manner of graduating jars for this purpose is very easy, and we ought to be provided with graduated jars of different sizes, and even several of each size. Take a tall, narrow, and strong glass jar, and, having filled it with water in the cistern, place it upon the shelf of the pneumatic trough, we ought always to use the same place for this operation, that the level of the shelf may be always exactly similar, by which almost the only error to which this process is liable will be avoided. Then take a narrow-mouthed phial holding exactly 10 cubical inches. If you have not one exactly of this dimension, choose one a little larger, and diminish its capacity to the size requisite, by dropping in a little melted wax and rosin. This small phial serves the purpose of a standard for gaging the jars. Make the air contained in this bottle pass into the jar, and mark exactly the place to which the water has descended; add another measure of air, and again mark the place of the water, and so on, till all the water is displaced. It is of great consequence that, during the course of this operation, the bottle and jar be kept at the same temperature with the water in the cistern; and, for this reason, we must refrain as much as possible from keeping the hands upon either, or, if we suspect they have been heated, we must cool them again by means of the water in the cistern. The height of the barometer and thermometer during this experiment is of no consequence. When the marks have been thus ascertained upon the jar, for every ten cubical inches we mark the scale upon one of its sides by means of a diamond pencil.

Glass tubes are graduated in the same manner for using as the mercurial apparatus, only they must be divided

into cubic inches, and tenths of cubical inches. The bottle for gaging these should hold one cubic inch.

Another mode of determining the volume of elastic aeriform fluids, consists in transferring the unknown volume of air into a narrow cylindrical vessel standing on the shelf of the pneumatic trough, and then marking by means of a slip of paper pasted on the jar the exact height of the elastic fluid. This being done we turn up the jar, and fill it with water exactly up to the mark, and by weighing the water, and reducing its weight to cubic inches, the volume of the gas may be found.

JAR, PRECIPITATING.—The most convenient jars for mixtures and precipitations are such as figs. 5, and 6, plate XI., or as those which are represented figs. 8, and 9, plate XVI. these being broad at bottom, any precipitate can be more thoroughlyedulcorated than in any vessel of the wine-glass shape. An assortment of glass jars of a cylindrical shape, or nearly so, are indispensably necessary in the laboratory, both for experiments on gasses, and for holding liquors in all the common operations of filtering, mixture, &c. For the gasses, the jars are usually plain cylinders of various length and capacity, which stand steadily enough when inverted over water, and the margin of the open end is generally ground smooth, that when any flat plate, or a circular bit of card, is pressed upon it, the water may not drop out when the jar is inverted. For experiments with mercury, the jars should be smaller and thicker, and to stand very steadily, jars are sometimes wider at bottom.

JAR, WIDE-MOUTH, fig. 3, plate XI., which can readily be rendered air-tight.—It is frequently necessary to close the openings of very wide-mouthed vessels in-

tended to contain substances which would be injured by free exposure to the atmosphere, or by evaporation. Ground glass stoppers are seldom air-tight, and when they are, it happens that by the accumulation of particles of dust in the fitting, the stopper soon becomes immovable. The method here adopted, is to have a glass jar, *a*, with a groove, *b*, half an inch deep round the outside of the pot or the mouth of the jar, and a glass lid, *c*, fitting loosely into the groove, which is rendered air-tight by hog's lard, a substance never quite fluid at the highest temperature of this climate, and always soft enough in the cold season to admit of removing the lid or the top of the jar.

JAR, DEFLAGRATING, fig. 21, plate IV.—See **AIR JAR**, page 38, and **BELL GLASS**, page 53.

LAMP, CHEMICAL, fig. 37, plate I.—This kind of lamp is very convenient for chemical purposes, being flat and low, the wick rises and falls by the motion of the small toothed wheel, this affords the facility of altering the position of the flame with regard to the vessel which remains fixed, at the same time that the flame itself can be brought near to the matter on which it is intended to act.

LAMP, SPIRIT, figs. 27, 28, plate I.—A Spirit Lamp, for experiments in the small way, which demand a moderate degree of heat, and much neatness, the spirit lamp is an excellent contrivance. The flame of burning spirit of wine being always perfectly clear, and free from smoke, produces no soot on the vessel on which it acts. It may easily be made to burn slower or faster, and consequently occasion more or less heat, by merely enlarging or diminishing the surface of the cotton wick upon which the

spirit burns ; for as long as the wick is freely supplied with spirit, the flame is precisely of the same strength. The burning of spirit is, besides, more clear and elegant than oil ; it gives no unpleasant smell, and does not produce any disagreeable consequences if spilt ; the wick of the lamp is not rendered foul, nor is it scorched or consumed, and the vessel to which the flame is applied does not become obscured by smoke. The expense of the spirit to supply the lamp for experimental purposes is quite inconsiderable. *a* is the lamp ; *c*. a glass cap fitted to the neck of the lamp by grinding, to prevent the evaporation of the spirit from the surface of the cotton when the lamp is not in use.

LAMP FURNACE.—See Furnace.

LENSES OR BURNING GLASSES have often been found useful in chemical researches, for applying the heat of the sun's concentrated rays upon bodies, under circumstances in which other heat cannot be applied, as on the inside of a glass bottle or receiver (fig. 18, plate 9) or in a vacuum ; they are usually fitted up as represented in figs. 18 and 19, plate IX.

LEVIGATING STONE, Fig. 1, plate IV.—Levigating or Porphyrasition is nothing but a more complete trituration. It is performed on a flat piece of porphyry, *a* or any other stone that is very hard, and has a very smooth surface, with the aid of a stone of the same degree of hardness, which is called a *mullar* *b*. The matter is spread out upon the slab of porphyry ; the workman then takes the mullar with both hands, and works it circularly, and in different directions, to grind the matter. That part of the mullar which comes in contact with the

slab, must not be perfectly flat; its surface should be a portion of a sphere with a very large radius; otherwise the matter would be driven before the mullar, and could not get underneath it to be ground. When the matter is too much spread on the surface of the porphyry, it may be brought back to the centre, by means of a knife with a very thin blade, fig. 14, plate XIV., of iron, horn, or ivory.

LEVIGATING MORTAR, Fig. 20, plate XVI.—Where substances are insoluble in water, the addition of water, so as to form them into a paste, may be usefully made, which is to be rubbed or levigated in a flat bottomed mortar till it is sufficiently fine; this prevents the loss and inconvenience of quantities of the finer powder being scattered about in the form of dust. Fig. 21 is the pestle of the mortar.

LIXIVIATING TUBS, *a, a, a*, Fig. 1, plate VII.—Lixivation is an operation used in chemistry for separating substances which are soluble in water from such as are insoluble. The large tub, *a, a, a*, having a hole *d* near its bottom, containing a wooden-spiggot and fosset, or metallic stop-cock, is generally used for this purpose. A thin stratum of straw is placed at the bottom of the tub; over this, the substance to be lixiviated is laid and covered by a cloth, then hot or cold water, according to the degree of solubility of the saline matter, is poured on. When the water is supposed to have dissolved all the saline parts, it is let off by the stop-cock; and, as some of the water charged with salt necessarily adheres to the straw and insoluble matters, several fresh quantities of water are poured on. The straw serves to secure a proper passage for the water, and may be compared to

the straws or glass rods used in filtrating, to keep the paper from touching the sides of the funnel. The cloth which is laid over the matters under lixiviation prevents the water from making a hollow in these substances where it is poured on, through which it might escape without acting upon the whole mass.

This operation is more or less imitated in chemical experiments; but as in these, especially with analytical views, greater exactness is required, particular precautions must be employed, so as not to leave any saline or soluble part in the residuum. More water must be employed than in ordinary lixiviations, and the substances ought to be previously stirred up with a stick in the water before the clear liquor is drawn off, otherwise the whole mass might not be equally lixiviated, and some parts might even escape altogether from the action of the water. We must likewise employ fresh portions of water in considerable quantity, until it comes off entirely free from salt, which we may ascertain by means of proper tests.

In experiments with small quantities, this operation is conveniently performed in jugs or matresses of glass, and by filtrating the liquor through paper in a glass funnel. When the substance is in larger quantity, it may be lixiviated in a kettle of boiling-water, and filtrated through paper supported by cloth in the wooden frame, and in operations in the large way, the tubs, *a, a, a*, must be used.

LUTES, See page 18.

MATRASS, fig. 36, plate I., fig. 7, plate IX.—The matrass is a glass vessel used for making solutions. It is generally of a spherical form, flattened slightly at bottom.

It has a long neck to allow the fluid to condense and return into the vessel. Glass matrasses should be thin at the bottom. The common flask, see fig. 36, plate 1. is a good matrass.

MEASURE GLASS, fig. 34, plate 1.—A conical glass vessel graduated into certain capacities either by weight or bulk to a standard fluid. Whenever exactness is required, which always ought to be most carefully attended to in chemical inquiries, quantities of fluids should seldom be determined by measure, but by weight. The measuring of fluids may in some few cases be allowed; but then it should be always mentioned for the information of those that will repeat the experiment, or reason on its results; and the more so when the same kind of fluid is of various specific gravities, or when particular accuracy is required.

The weights and measures required by the chemist are few and simple, but they should be accurate, and their relative values well defined.

For the measure of weight, the Troy pound of 12 ounces or 5760 grains, is the integer almost always preferred, being that which admits of a minuter subdivision, and whose correspondences with measures of capacity are more accurately defined; though there are still some slight differences in this respect which it were to be wished were removed by authority. The subdivisions of the troy ounce employed by chemists are sometimes those of apothecaries weight, that is the ounce into eight drams, the dram into three scruples, and the scruple into twenty grains, or more commonly, simply into drams and grains; or sometimes the ounce is divided into twenty pennyweights, and the pennyweight into twenty-four grains. Often the grain is the only integer employed, and sets of

weights are used of the different hundreds, tens, and units. The averdupois pound is however sometimes adopted, being the standard of most things bought and sold in common life. It is equal to 7000 grains troy, and is divided into sixteen ounces, and the ounce legally into sixteen drams, but the latter division is never used by chemists, being liable to be mistaken for the troy dram, which weighs more than twice as much.

For measures of capacity, chemists employ both the ounce measure (or bulk occupied by the ounce, or any proportion of it, of distilled water at 60°) and the cubic inch. For larger quantities both the wine pint of 28,875 cubic inches, and the ale pint of 35.25 cubic inches are used. Two pints make a quart, and four quarts make a gallon.

The correspondence between measures of weight and capacity is found by the weight of a cubic inch of water. In this however a slight difference exists, in authorities apparently equally worthy of confidence, which depends partly on the extreme difficulty of constructing instruments of perfect accuracy, and partly on some slight discrepancy between the standards themselves. The extent of this difference is about half a grain in 253. We have adopted in the following tables the estimations given by Sir G. Shuckburgh Evely, in the 88th vol. of the *Philosophical Transactions*, corrected in a subsequent paper by Mr. Fletcher, in the 4th vol. of the *Philosophical Journal*. On this calculation the cubic inch of distilled water at 60° thermometer, and 29.5 barometer, weighs 252.506 grains troy.

Hence we have the following equations :

	<i>Cubic inch.</i>		
1 ounce Troy of water at 60° occupies	1.900945		
1 Wine pint of water weighs	7291.11075	$\div 1.26581783 =$	1.04158725
	<i>Grs. Troy.</i>	<i>lb. Troy.</i>	<i>lb. Averd.</i>
1 Ale pint of water weighs	8900.8365	$\div 154284 =$	1.271548
	<i>Grs. Troy.</i>	<i>lb. Troy.</i>	<i>lb. Averd.</i>
1 lb. Troy of water occupies7900031	$\div .6471302 =$	
	<i>Wine pint.</i>	<i>Ale Pint.</i>	
1 lb. Averdupois of water occupies960073	$\div .7864429 =$	
	<i>Wine pint.</i>	<i>Ale pint.</i>	

We may here notice the very common error of estimating a wine pint of water to be equal to sixteen ounces troy, since it wants as much as 380 grains of sixteen ounces, when the cubic inch is estimated at 252,506 grains and 375 grains, when the cubic inch is reckoned 253 grains, which is the highest estimation. Nevertheless as several measuring vessels are thus graduated, and as the adoption of this standard would be extremely convenient, this measurement may be often usefully employed for moderate quantities; but the chemist should then express that he uses the pint of sixteen ounces troy.

A totally new system of weights and measures has been introduced into the French empire, and is that in which most of the expressions of quantities in chemical experiments are now made. It is therefore necessary in this place to give their corresponding quantities in English measures.

‘ To employ, as the fundamental unity of all measures, a type taken from nature itself, a type as unchangeable as the globe on which we dwell—to propose a metrical system, of which all the parts are intimately connected together, and of which the multiples and subdivisions follow a natural progression, which is simple, easy to comprehend:—this is most assuredly a beautiful, great, and sublime idea, worthy the enlightened age in which we live.’

Such were the ideas which influenced the French National Institute, when they chose, as the base of the whole metrical system, the fourth part of the terrestrial meridian, between the equator and the north pole. They adopted the ten millioneth part of this arc for the unity of measure, which they denominated *metre* and applied it both to superficial and solid measures, taking for the unity of the former, *arc*, the square of the decuple, and for that of the latter, *litre*, the cube of the tenth part of the metre. They chose for the unity of weight, *gramme*, the quantity of distilled water which the same cube contains when reduced to a constant state presented by nature itself: and lastly, they decided, that the multiples and submultiples of each kind of measure, whether of weight, capacity, or length, should be always taken in the decimal progression, as being the most simple, the most natural, and the most easy for calculation, according to the system of numeration which all Europe has employed for centuries, and they used the prefixes, *deca*, *hecto*, *kilo*, and *myria*, taken from the Greek numerals, to express the multiplication of the integer by 10, 100, 1000 and 10,000 respectively, and *deci*, *centi*, *milli*, taken from the latin numerals, to express its division.

By a careful measurement of the arc between Dunkirk and Mountjoy, they found the length of the metre to be equal to 443.296 lines of the toise of Peru. The cubic decimetre of distilled water, taken at its maximum of density and weight in *vacuo*, that is, the unity of weight was found to be 18827.15 grains of the pile of Charlemagne.

The *metre* at 32° = 39.371 Eng. inches at 62°.
 The square metre 1550.075641 Eng. sq. inches.
 The square decimetre 15.50075 Eng. sq. inches.
 100 *arcs* or square decimeters = 2 English acres nearly.

Cub. feet. cub. inch.

The cubic metre = 61028.028 Eng. cubic in = 355 48.028
 The cubic decimetre, or *litre* = 61.028 Eng. cubic inches.

Equal to the bulk of a killogramme of water.

The gramme or weight of a cubic centimetre of water
 equal to 15.44402 troy grains.

MEASURES OF LENGTH.

The Metre being at 32°, and the Foot at 62°.

	<i>English inches.</i>				
Millimetre	= .03937				
Centimetre	.39371				
Decimetre	3.93710				
Metre	39.37100	<i>Mil.</i>	<i>Fur.</i>	<i>Yrds.</i>	<i>Feet Inch.</i>
Decametre	393.71000	0	0	10	2 9.7
Hecatometre	3937.10000	0	0	109	1 1
Kilometre	39371.00000	0	4	213	1 10.2
Myriometre	393710.00000	6	1	156	0 6

<i>Metre.</i>	<i>Eng. feet</i>	<i>Inches.</i>	<i>Decimetre.</i>	<i>Eng. inches.</i>
1	= 3 :	3.371	1	= 3.9731
2	6 :	6.742	2	7.8742
3	9 :	10.113	3	11.8113
4	13 :	1.484	4	15.7484
5	16 :	4.855	5	19.6855
6	19 :	8.216	6	23.6226
7	22 :	11.597	7	27.5597
8	26 :	2.968	8	31.4968
9	29 :	6.339	9	35.4339

MEASURES OF CAPACITY.

	<i>Cubic inches.</i>		<i>ENGLISH.</i>			
Millilitre	=	.06103				
Centilitre		.61028				
Decilitre		6.10280				
Litre		61.02800	=	0	0	0 2.1133
Decalitre		610.28000		0	0	2 5.1352
Hecatolitre		6102.80000		0	0	26.419
Kilolitre		61028.00000		1	0	12.19
Myrialitre		610280.00000		10	1	58.9

<i>Litre.</i>	<i>Eng. cub. inch.</i>	<i>Ale pints.</i>	<i>Wine pints.</i>	<i>Oz, troy of water.</i>
1 =	61.028 =	1.7313 =	2.11353 =	31.104
2	122.056	3.4626	4.22706	64.208
3	183.084	5.1939	6.34059	96.312
4	244.112	6.9252	8.45412	128.416
5	305.140	8.6565	16.56765	160.520
6	366.168	10.3878	12.68118	192.624
7	427.196	12.1191	14.79471	224.728
8	488.224	13.8504	16.90824	256.832
9	549.252	15.5817	19.02177	288.936

MEASURES OF WEIGHT.

	<i>English grains.</i>		<i>AVOIRDUPOIS.</i>		
Milligramme	.0154				
Centigramme	.1544				
Decigramme	1.5444				
Gramme	15.4440		<i>Pounds.</i>	<i>Oun.</i>	<i>Dram.</i>
Decagramme	154.4402 =		0	0	5.65
Hecatogramme	1544.4023		0	3	8.5
Kilogramme	15444.0234		2	3	5
Myriogramme	154440.2344		22	1	2

<i>Gram.</i>	<i>Troy grs.</i>	<i>Deca- Gram.</i>	<i>Troy dram. grs.</i>	<i>Hecto- gramm.</i>	<i>Troy oz.</i>	<i>Avoird. oz.</i>
1 =	15.444	1 =	2 : 34.44	1 =	3.2175 =	3.5279
2	30.888	2	5 : 8.88	2	6.4350	7.0558
3	46.332	3	7 : 43.32	3	9.6525	10.5837
4	61.776	4	10 : 17.76	4	12.8700	14.1116
5	77.220	5	12 : 52.20	5	16.0875	17.6395
6	92.664	6	15 : 26.64	6	19.3050	21.1074
7	108.108	7	18 : 1.08	7	22.5295	24.6953
8	123.552	8	20 : 35.52	8	25.7400	28.2232
9	138.996	9	23 : 9.96	9	28.9575	31.7511

The decimal progression of all the French weights and measures renders it only necessary to change the decimal point in order to convert one into the equivalent of any other of the same species and numerically the same, but of a different denomination. Thus as 9 litres are equal to 15.5817 ale pints, 9 hectolitres will be equal to 1558.17 ale pints: and so of the rest.

MERCURIAL TROUGH.—See **PNEUMATIC TROUGH.**

MEPHITIC WATER APPARATUS, fig. 9, plate V.—*a* is a copper bottle connected with a condensing syringe *b*. The carbonic acid is generated in the usual manner, and conveyed, by means of the bell glass *c*, into the copper ball. This apparatus is but ill calculated for the purpose of impregnating water with carbonic acid.

MORTAR.—Pounding is one of the most common operations of the laboratory. The chemist must therefore be provided with mortars of different kinds, glass, wood, iron, steel, marble, siliceous stones, and porcelain ware, are all employed. The nature of the substance which the chemist has occasion to pound must direct him in the choice of one mortar in preference to another. He must have glass mortars for pulverising corrosive saline substances, these are usually of the form represented fig. 13, plate XVI. For bruising succulent herbs, roots, and other recent vegetable substances, which do not require trituration, mortars made of box-wood, or oak, are used; these are shaped as represented fig. 18, plate XVI., fig. 19 is the cover belonging to the mortar.

It is scarcely necessary to observe, that in order that the matter may be properly subjected to the effort of the pestle, the bottom of mortars must be of a concave form

and the side should neither be so inclined as not to allow the substance operated on to fall to the bottom between each stroke of the pestle, nor so perpendicular as to collect it too much together, and to retard the operation.

Fig. 13, plate VII. represents an iron mortar of an improved form with its cover. It differs from the ordinary shape of mortars, in being nearly circular instead of conical; by this means substances are more readily comminuted, and are not subject to be thrown out of the mortar by the effort of the pestle; tenacious substances are not so subject to cake, and a better effect is produced in many instances by giving a rotatory motion to the pestle, which cannot be effectually accomplished in the mortar of the usual forms. To prevent the finest and lightest parts of the powdered substance from escaping, and to defend the operator from the effects of disagreeable or noxious substances, the top of this mortar is so constructed as to admit a wooden cover within a rim or groove, a mode more effectual than the old contrivance of covering the orifice of the mortar with a mere perforated cover. The pestle has a hole in the upper extremity, in order to suspend it if required. Figs. 12 and 13, plate VII. shew the shape of the larger kinds of cast iron, or what are commonly called laboratory mortars. They are always provided with wooden covers to prevent the finest and lightest parts from escaping, and to defend the operator from the effects of disagreeable or noxious substances. But these ends are more completely attained, by tying a piece of pliable leather round the pestle and round the mouth of the mortar. It must be closely applied, and at the same time so large, as to admit the free motion of the pestle.

In some instances, it will be even necessary for the operator to cover his mouth and nostrils with a wet cloth,

and to stand with his back to a current of air, that the very acrid particles which arise may be carried from him. To lessen the manual labour, the pestle of large mortars is fastened to the end of a flexible wooden pole, which hangs over the mortar, by the elasticity of which the pestle is lifted up again to the proper height after the stroke is made. Fig. 15, plate VII. is a *Steel Mortar* for pulverising gems. It consists of a solid cylinder of hardened steel, having a slight concavity, to which is fitted the steel pestle, fig. 14. The block of steel is fixed into an outer wooden case. The gems to be pulverised by means of this mortar, must first be crushed into small fragments by means of the *Crushing Mortar*, represented fig. 17, plate VII., which consists of a cylinder of hardened steel, with a flat bottom, and a pestle of the same, made to fit the mortar accurately from top to bottom. It is used by putting the gems, or pieces of hard mineral, into it, and striking the pestle with a hammer. By this means the substance can be reduced into tolerable small fragments, without grinding off any portion of the mortar. The fragments are then collected, and put into the mortar with a little water, and a very close continued friction is required to bring it into an impalpable powder. It should always be remembered, that when a very hard body is ground to powder, the friction wears the mortar as well as the substance pulverized, consequently for delicate experiments it is necessary to weigh the mortar before and after the process, and to allow for the loss of weight by an equivalent addition to the powder obtained. Fig. 20, plate XVI. shews the usual shape of agate or flint mortars employed for pulverising minute quantities of hard minerals for chemical analysis, fig. 21 is the pestle of the agate mortar. Very useful hand mortars are also made of

hard iron, turned, (smooth within) which are very hard. For grinding substances of moderate hardness, mortars made of wedge-wood ware, figs. 11 and 12, with very smooth pestles of the same materials, are extremely useful. They will readily break, however, by a smart blow. For lighter purposes very good mortars are made of bell-metal, with pestles either of the same or of iron. They are cast very smooth, so that the material to be pounded does not stick to the sides. Most neutral salts may be conveniently pulverized in them, but their chemical action on the copper ought to be kept in mind, as (for example) if muriate or carbonate of ammonia be left in a bell-metal mortar it becomes green by the oxyd of copper which it dissolves.

MUFFLE, figs. 15 and 16, plate I.—A muffle is a vaulted flat-bottomed earthen vessel, intended to be put in the midst of a furnace, of proper construction, so as to afford a space strongly heated, but protected from the actual contact of the fuel, in which small vessels of any kind may be set. The muffle is entirely open at one end and closed at the other, and it has sometimes slits or openings at its sides, as shewn in fig. 16.

NOOTH'S APPARATUS, fig. 8, plate VI.—When habitual use is made of water impregnated with carbonic acid gas, the apparatus of Dr. Nooth is very effectual and convenient. It consists of three glass vessels. The lower vessel *c* contains the effervescent materials: it has a small orifice *d*, stopped with a ground stopper, at which an additional supply of ether, muriatic, or sulphuric acid, or chalk, may be occasionally introduced. The middle vessel *b* is open both above and below. Its inferior neck is fitted by grinding into the neck *h* of the

lower vessel. In the former is a glass valve, formed by two pieces of tube, and a lens, which is moveable, between them. This valve opens upwards, and suffers the gas to pass; but the water cannot return through the tubes, partly because the orifice is capillary, and partly because the flat lens covers the hole. The middle vessel is furnished with a cock *E*, to draw off its contents. The upper vessel *A* is fitted, by grinding, into the upper neck of the middle vessel. Its inferior part consists of a tube that passes almost as low as the centre of the middle vessel. Its upper orifice is closed by a ground stopper *r*. When this apparatus is to be used, the effervescent materials, chalk or marble, and dilute sulphuric acid are put into the lower vessel; the middle vessel is filled with water, and put in its place, and the upper vessel is nearly stopped, and likewise put in its place. The consequence is, that the carbonic acid gas, passing through the valve at *H*, ascends into the upper part of the middle vessel *B*, where, by its elasticity, it re-acts on the water, and forces part up the tube into the vessel *A*; part of the common air, in this last, being compressed, and the rest escaping by the stopper, which is made of a conical figure, that it may be easily raised. As more gas is extricated, more water rises, till at length the water in the middle vessel falls below the lower orifice of the tube. Carbonic acid gas then passes through the tube into the upper vessel, and expels more of the common air by raising the stopper. In this situation the water in both vessels, being in contact with a body of carbonic acid, becomes strongly impregnated with that fluid after a certain time. This effect may be hastened by taking off the middle and upper vessels together, and agitating them.

The valve is the most defective part of this apparatus; for the capillary tube does not admit the air through, un-

less there be a considerable quantity condensed in the lower vessel, and the condensation has in many instances burst the vessel. Fig. 9 shews the valve of the apparatus.

OXY-HYDROGEN BLOWPIPE, (see page 60).

—Another oxy-hydrogen blowpipe has been invented by Mr. Gurney, and seems to have strong claims to attention. Notwithstanding all the ingenious contrivances for rendering safe the oxy-hydrogen blowpipe, as described at page 60, it still continued liable to explosions, and many persons have been deterred from using it on that account. The effects capable of being produced by this instrument constitute such brilliant exhibitions, tend so much to the enlargement of the sphere of knowledge, and to the improvement of the useful arts, that it is much to be regretted its application should be so confined, on account of the danger to which the use of it is subject.

Mr. Gurney has discovered that explosions may be much more effectually prevented, by interposing a chamber containing a small portion of the inflammable gas between the jet and reservoir of gas, than they can be by the usual method of interposing small tubes or wire gauze. Having noticed that very strong mechanical pressure applied to the gas in his blowpipe had the effect of extinguishing the flame when it was burning, and of preventing the gas from taking fire at the jet when it was not burning, it occurred to him that the explosion of a small quantity of gas in a chamber behind the jet pipe might have the same effect, and he found it to be so on trial. So that his contrivance to render the oxy-hydrogen blowpipe safe is to place a small metallic chamber behind the orifice at which the gas is enflamed. Should the flame pass backward, the gas in this small chamber will explode with-

out injury, and the flame will be extinguished. To add still greater security, the instrument is furnished with another chamber containing water, through which the gas is made to pass, and which would oppose the passage of the flame backwards; but so confident is the ingenious inventor in the protecting power of the exploding chamber, that in many of his experiments he does not use the water vessel.

Fig. 10, plate XII. is a representation of this blow-pipe. *a* is the safety chambers, *b* is the water vessel, through which the gas must pass from the gasometer *d* by the stop-cock *c*, and through a tube which reaches to the bottom of the water and turns up a little; *e* is a cock, which in case explosion happens on the surface of the water is thrown up, and which takes out to admit water to be poured into the trough when first used; *f* a gauge which is to indicate the necessary height of the column of water in the trough; *g* a transferring bladder, which screws and unscrews to and from the stop-cock *h*, by which the gasometer is charged by an assistant during its action, and the quantity of gas supplied so as to keep up a flame for any length of time. Between the gasometer and the charging bladder there is a valve placed to prevent a return of the gas; *i i* a light paste-board or wood case contrived so as to unite lightness with strength, which in case an explosion of the gasometer happens, is thrown into the air by the force rupturing the strings by which it is kept down; from its extent of surface and great lightness it will be instantly arrested by the action of the atmosphere. To these strings are attached small wires, which pass through holes in the table of the instrument *l*, and are again affixed to a moveable pressboard below *m*; this pressboard is regulated and kept in a horizontal position by

the perpendicular stand *n*, so that when the necessary weight or pressure is placed on it, it may draw the cap *i* horizontally and equally on the gasometer *d*. The gasometer bladder or silk bag is tied to a bladderpiece, which screws into a long tube, laid into and across the table of the instrument. This bladderpiece, to which the gasometer is tied, permits it to be unscrewed from the table at pleasure, and immersed in warm water, to render it soft when occasion requires; or in case an accident happens to it, allows another to be tied on. To one end of the tube which is let into the table of the instrument, the stop-cock of the charging-bladder is attached, and to the other the stop-cock of the water trough.

When the cap is drawn on the bladder or silk bag constituting the gasometer, the gas is forced through the stop-cock, water tube, and ultimately through the safety chamber and the jet, at the opening of which it is burnt.

The inventor states that this blowpipe may be successfully applied in some important operations of the arts, and that it may also be successfully applied in resolving mineral substances into their constituent parts.

OXYGEN GAS HOLDER.—The most convenient apparatus for holding considerable quantities of oxygen or hydrogen is that which has been improved by Mr. Pepys (fig. 7, plate XI.) It consists of a japanned iron or copper vessel, *a* is the part which contains gas, and is usually made capable of holding from six to eight gallons. *b* is a cistern for holding water having two tubes opening into it. These tubes supplied with stop-cocks are seen at *c* and *d* underneath the cistern, the middle one *d* is continued nearly to the bottom of the vessel; the other one *c* opens into the lower vessel *a*, but is not continued downwards. In order to fill this vessel with water, the

aperture *f* is closed with its screw, the stop-cocks *c*, *d*, *e*, being all open, water is poured into the cistern above (the funnel and tube which unscrew at the bottom of the cistern being removed), and it descends through the tubes and stop-cocks *c* and *d*, and forces the air out at *e*; when the gas holder is nearly full, the stop-cock *e* must be closed, and what remains of the air will find its way out through *c*, until the vessel is full, the stop-cock must then be closed. To fill the vessel with oxygen gas, an iron bottle containing black oxide of manganese is put into the fire; and a communication being made between the bottle and the gasholder by a metallic tube, which is introduced at the aperture *f*, as soon as the iron bottle attains the temperature of a red heat gas comes over, and ascending through the water occupies the upper part, the water descends and flows out at the aperture as the gas goes in. The tube *g* is of glass, and has a communication at top and bottom of the gasholder, and shews the progress of its filling and the quantity of gas which it contains at any time. When the vessel is sufficiently filled with gas, the aperture *f* must be closed effectually. The gas will then be ready for use. If the gas is to be transferred into a bladder, a connecting piece must be screwed on at *e*, and the bladder, previously furnished with a stop-cock, is screwed to the connecting piece, the cistern must then be filled with water, and the stop-cocks *d* and *e* opened, the water will descend the tube *d*, compress the gas, and cause it to issue at *e* into the bladder; when the stop-cocks are closed the bladder may be withdrawn.

To transfer gas into a bottle or jar, the vessel which is to receive the gas must be filled with water, and its mouth placed downwards, over the hole above the stop-cock *c*; this stop-cock must be opened, and also the stop-

cock at *d*, the water will then descend by the long tube in the centre *d*, compress the air, and cause it to ascend through *c* into the bottle or jar, which must be held a very little on one side, that the water may be able to descend out of the bottle uninterrupted by the close contact of the mouth of the bottle and the bottom of the cistern. When the bottle is full, and the stop-cocks closed, it may be removed by introducing a cork under water; the bottle may then be turned with its mouth upwards. When a jar which is open at the bottom is filled, it may be removed by slipping a shallow dish under the open part, below the surface of the water, the gas will be prevented from escaping by the water in the shallow dish, that rises a little way above the jar or receiver.

It will be remembered that, during all the operations which have been described, the funnel and long tube is removed by unscrewing it at the bottom of the cistern; the use of this part of the apparatus is now to be described. By screwing it on, as it is represented in the figure, and also the jet pipe *i*, the apparatus is converted into an excellent hydraulic blowpipe, while it is kept full of water to the top of the funnel *h*. When filled with oxygen gas it is capable of producing a very intense heat.

This gasholder is chiefly used for oxygen and hydrogen, but occasionally for other gases.

PAN for Boiling Tar, Turpentine, Pitch, or other inflammable fluids, fig. 44, plate I.—*a b c* are the body of the pan, *d e f* a long spout proceeding from it, for preventing any risk of boiling over; *g*, a short spout for pouring out. The pan should not be filled above $\frac{3}{4}$ of its capacity; and the long spout, *d e f*, should be placed so

as to be as little heated as possible. When the fluid begins to swell and boil up, both from the great increase of surface, and from part of it running up the cooler spout, *d e f*, the ebullition will be checked, and all danger of running over prevented.

The pans used in laboratories, fig. 2, plate VIII., figs. 10 and 16, plate XVI., and fig. 8, plate II., requires no description. They are employed to concentrate and thicken liquids, or to separate salts or other substances.

PELICAN, fig. 5, plate IX.—A pelican is a glass alembic, consisting of one piece. It has a tubulated capital, from which two opposite and crooked beaks pass out, and enter again at the belly of the cucurbit. This vessel has been contrived by the alchymists for a continued distillation, which they call circulation. The volatile parts of substances put into this vessel rise into the capital, and are obliged to return through the crooked beaks into the cucurbit; and this without interruption, or luting or unluting the vessels.

Although the pelican seems to be a very convenient instrument, it is nevertheless little used, because two matrasses or flasks, fig. 1, plate I. the mouth of one of which is inserted in the mouth of the other, produce the same effect.

PHOSPHORUS ACID APPARATUS, fig. 4, plate III.—If phosphorus be exposed in atmospheric air, it burns slowly, and exhales smoke from its whole surface. This vapour, which emits a strong smell of garlic is phosphoric acid.

Take several glass tubes the lower extremities of which are made to taper, so as to end in a small orifice sufficient to afford a passage to the drop of acid which is produced.

Put into each a stick of phosphorus, and when thus prepared, arrange them in a large funnel, stuck in a bottle. The whole apparatus must be placed on a broad dish, containing water, and must be covered with a bell having apertures in its sides, in order to guard against dust, and that there may be always a supply of moist air, which greatly accelerates the decomposition of insensible combustion of the phosphorus. Fig. 9, plate III. exhibits a convenient apparatus for the production of phosphorus acid.

Pelletier has taught us another process. One part of his apparatus consists of a long cylinder, into which phosphorus is put with water, the cylinder is then placed in a bocal, and a supply of boiling water is maintained around it, in order to keep the phosphorus in a liquid state. The other part is a bent tube, one end of which is thrust into the phosphorus, and the other fitted to a large receiver, having a second aperture, to which is adjusted a funnel with a cock. When the apparatus is thus arranged, water is put into the funnel, and by opening the cock it enters the receiver, and forces the air contained in it to pass through the tube. This air in passing through the phosphorus combines with it, and produces a combustion of the phosphorus, which by these means is converted into phosphoric acid.

When the receiver is full of water, it may be emptied by a cock inserted in the lower part of it.

PHOTOMETER, (LESLIE'S,) figs. 3 and 5, plate XIII. For measuring the intensity, or at least the calorific action of light, no instrument is so finely adapted by its peculiar delicacy as the *Photometer* of Leslie, which consists of a *Differential Thermometer*, inclosed in a thin pellucid case, and having one ball *a*, made of black and the other of

clear glass. Yet, owing to a combination of circumstances this elegant instrument has only been partially and reluctantly admitted; and the philosophic world has still to discharge an act of justice to Professor Leslie, by receiving it into the favour and distinction which it so well deserves. Some, indeed, affecting to display superior sagacity, have taken the trouble to remark that it was only a species of thermometer; and not strictly a photometer, since it measures heat, and not light. But what does the thermometer itself indicate, except *expansion*? As heat is measured by the expansion it occasions, so light is determined by the intensity of the heat, which in every supposition, invariably accompanies it. What other mode, after all, could be imagined for detecting the presence of light? How can an unknown quantity be expounded, but in terms of one already known?

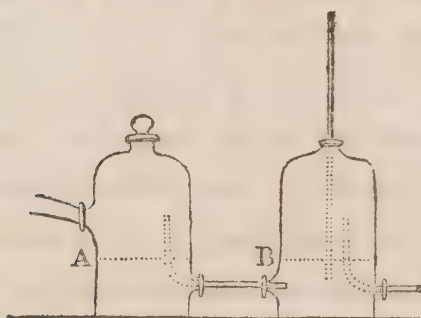
Leslie's photometer has two general forms; the one *portable*, fig. 3, in which the black ball, *a*, is about an inch higher than the other, and bent forward to the same vertical line, or the axis of the translucent cylindrical case, and the other *stationary*, having both its balls of the same height, and reclining in opposite ways; the case being composed of a wide cylinder, surmounted by the larger segment of a hollow glass sphere. The portable thermometer admits likewise an outer wooden case of mahogany, which not only protects it from risk or injury, but occasionally serves, when out of doors, for holding it in an erect position. The other form of the instrument, (fig. 5,) however, though in some respects less commodious, is yet, on the whole, better adapted for nice observations, since besides receiving the light more regularly, its balls, from being on the same level, are not liable to be any how disturbed in their indications by the different strata of unequally heated air.

The rays which fall on the clear ball, *b*, pass through it, without suffering obstruction ; but those which strike the dark ball are stopt and absorbed at its surface, where, assuming a latent form, they act as heat. This heat will continue to accumulate, till its farther increase comes to be counteracted by an opposite dispersion, caused by the rise of temperature which the ball has acquired. At the point of equilibrium, therefore, the constant accessions of heat derived from the action of the incident light, are exactly equalled by the corresponding portions of it, again abstracted in the subsequent process of cooling. But, in still air, the rate of cooling is, within moderate limits, proportioned to the excess of the temperature of a given surface above that of the surrounding medium. Hence the space through which the coloured liquid sinks in the stem, will measure the momentary impressions of light or its actual intensity. To prevent any extraneous agitation of the air from accelerating the discharge of heat at the surface of the black ball, and thereby diminishing the quantity of aggregate effect, the instrument is always sheltered, and more especially out of doors, by a thin glass case. The addition of this translucent case is quite indispensable. It not only precludes all irregular action, but maintains, around the sentient part of the instrument, an atmosphere of perpetual calm. Under the same force of incident light, the temperature of the black ball must still rise to the same height above that of its encircling medium. The case will evidently have some influence to confine the heat actually received, and hence to warm up the internal air. Wherefore, corresponding to this excess, the black ball will acquire a farther elevation of temperature ; but the clear ball, being immersed in the same fluid, must experience a similar effect, and which will exactly counterbalance the former. The difference

of temperature between the opposite balls, thus continues unaltered; and neither has the size or the shape of the case, nor the variable state of the exterior atmosphere with respect to rest or agitation, any influence whatever to derange or modify the results exhibited by this delicate instrument. The photometer exhibits distinctly the progress of illumination from the morning's dawn to the full vigour of noon, and thence its gradual decline till evening has spread her sober mantle; it marks the growth of light from the winter solstice to the height of summer, and its subsequent decay through the dusky shades of autumn; and it enables us to compare, with numerical accuracy, the brightness of different countries,—the brilliant sky of Italy, for instance, with the murky air of Holland.

The photometer is adapted for a variety of meteorological researches. If such instruments, in the hands of skilful observers, had been dispersed to the remote regions of the globe, we should ere now have obtained a body of precise facts, highly instructive in themselves, and calculated to illustrate the nature of different climates.

PNEUMATIC DISTILLATORY APPARATUS,
(Dr. DE BUTT'S) This name is given to a very convenient distillatory apparatus, invented by Dr. De Butt of Baltimore. It consists (as shown in the subjoined sketch) of two or more bottles.



The first bottle *a*, is connected by a tubulature with the tube of a retort, or an adapter; nigh the bottom, on the opposite side is another tubulature, and in the next bottle *b*, at the same height from the bottom, is a similar opening; these are connected by a straight tube without, which has such a curvature within the bottle *a*, as to rise above the water employed to condense the gas, the surface of which is represented by the dotted line: the succeeding bottles are connected in a similar manner. It is obvious that the gas passes forward through the bent tube, and is transmitted through the water in the next bottle; the tubes may be fitted by grinding, but it is difficult to have this done with perfect closeness: they may therefore be inserted by corks waxed; and as these are not exposed directly to the gas, but are under the liquid, they will in general be little acted on. Tubes of safety are adapted in a similar manner; and as it is inconvenient to detach the bottles, the liquor, when the distillation is completed, may be drawn off by a syphon,

inserted by the orifice at the upper aperture, or by an aperture in front at the bottom, fitted accurately with a stopper. The peculiar advantage of the apparatus is, that all the joinings, with the exception of the first, are under water, and the gas, therefore, cannot escape. Hence, in distillations in which the product is peculiarly offensive, as in that of chlorine, it affords the best security against any noxious effect.

PNEUMATIC TROUGH, OR CISTERN.—The discovery of gaseous fluids has, in modern chemistry, occasioned the necessity of some peculiar instruments, by means of which those substances may be caught, collected, and properly managed. The instruments for this are styled the *pneumatic apparatus*.

a, Fig. 15, plate IV. *q*, fig. 14, plate II. or figs. 16, 18, plate II. or *q*, fig. 42, plate I. represent a wooden or metal vessel, or tub; *k*, fig. 14, and fig. 18, plate II. fig. 15, plate IV. is a shelf fixed in the tub. When this apparatus is used, the trough is to be filled with water to such an height as to rise about one inch above the upper surface of the shelf. *a* is a glass jar inverted with its mouth downwards, which rests upon the shelf. If this, or any other vessels open only at one end, be plunged under the water, and are inverted after they are filled, they will remain full, notwithstanding their being raised out of the water, provided their mouths be kept immersed; for in this case the water is sustained by the pressure of the atmosphere in the same manner as the mercury in the barometer. It may without difficulty be imagined, that if common air, or any other fluid resembling common air in lightness and elasticity, be suffered to enter these vessels, it will rise to the upper part, and the surface of the water will subside. If a bottle, a cup, or any other vessel in

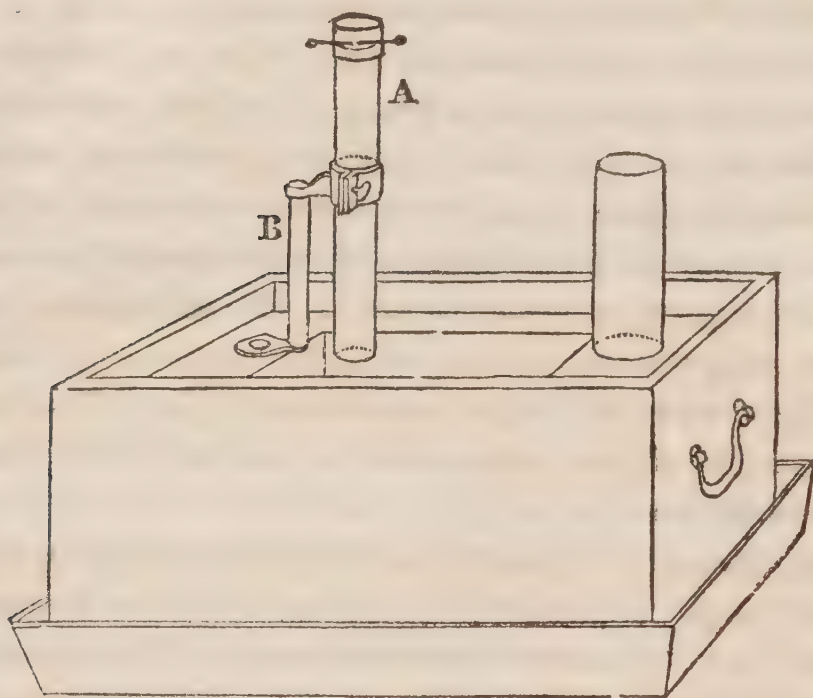
that state which is usually called empty, though really full of air be plunged into the water, with its mouth downwards, scarcely any water will enter, because its entrance is opposed by the elasticity of the included air; but if the vessel be turned up, it immediately fills, and the air rises in one or more bubbles to the surface. Suppose this operation to be performed under one of the jars which are filled with water: the air will ascend as before: but instead of escaping, it will be detained in the upper part of the jar. In this manner, therefore, we see that air may be emptied out of one vessel into another, by an inverted pouring, in which the air is made to ascend from the lower to the upper vessel, in which the experiments are performed by the action of the weightier fluid, exactly similar to the common pouring of denser fluids, detained in the bottoms of open vessels by the simple action of gravity. When the receiving vessel has a narrow neck, the air may be poured through a glass funnel. Thus the apparatus, fig. 17, plate II., is an extemporaneous pneumatic trough. It consists of a common earthen-ware wash-hand basin, across the rim of which is placed a board four or five inches wide, and about $\frac{3}{4}$ of an inch thick, having a slit terminating in a hole, cut in the centre of the board, which hole serves to receive the inverted common quart bottle, as shown in the drawing. The flask of the apparatus is furnished with a bent glass tube, which connects it with the bottle, and serves to convey the gas from the flask to the bottle; for one extremity of this tube passes air-tight through the cork in the neck of the flask, whilst the other end is inserted into the neck of the inverted bottle, *a*; fig. 15, plate IV. is one of the most convenient kinds of pneumatic trough, for private use, it is made of thin tinned iron japanned, generally 18 inches long, 9 broad, and 14 deep.

About $3\frac{1}{2}$ inches from the top is the shelf *k*, of the same material, extending entirely across the trough, and rather more than a third of its length, and fixed in its situation, when required, by two strong wires. A trough of this size and construction is very light when empty, and large enough for most operations.

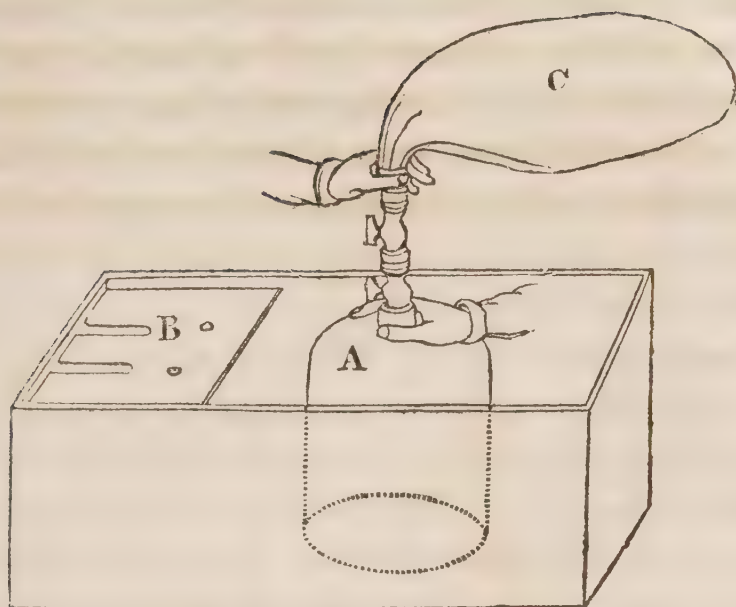
PNEUMATIC TROUGH, MERCURIAL, Fig. 7, and 27, plate IV. and fig. 8, is a transverse section of fig. 8.—Many kinds of gases combine with water, and therefore require to be managed in a trough in which quicksilver is made use of. This fluid being very ponderous, and of considerable price, is an object of convenience as well as of economy, that the trough and vessels should be much smaller than when water is used. To accomplish this object only one side of the trough is sunk deep, being equally convenient for the immersion of a jar. The shelf in a trough of this construction is on each side of the well, as shown *b, b*, in fig. 8.

Fig. 27, plate IV. is a very convenient pneumatic mercurial trough. It consists of a mahogany box *a, b*, standing in a tray *c*, made of the same wood. The principal parts of this apparatus are, the shelves of the trough and the bottom. The reservoir, properly so called, is the interval between these two planes. The advantage of this apparatus consists in having a broad solid shelf on one side of the trough, as shewn in fig. 8, plate IV., and a narrow sliding shelf, with a hole in the centre, which communicates with a funnel shaped opening on the side of a large shelf. Vessels placed on the sliding shelf may be conveniently filled with gas, by directing the conveying tube of a gas bottle, or the neck of a retort into this excavation, and then sliding it on the large shelf

of the apparatus, which, from being on one side of the trough, enables the operator to perform his experiments with a less quantity of mercury, and in an easier manner than in the troughs of the usual construction. The tray *a*, is useful for collecting mercury which may be spilled. The following sketch renders the construction of the trough more obvious.



The following sketch exhibits the method of transferring gases, by means of the pneumatic trough into bladders.



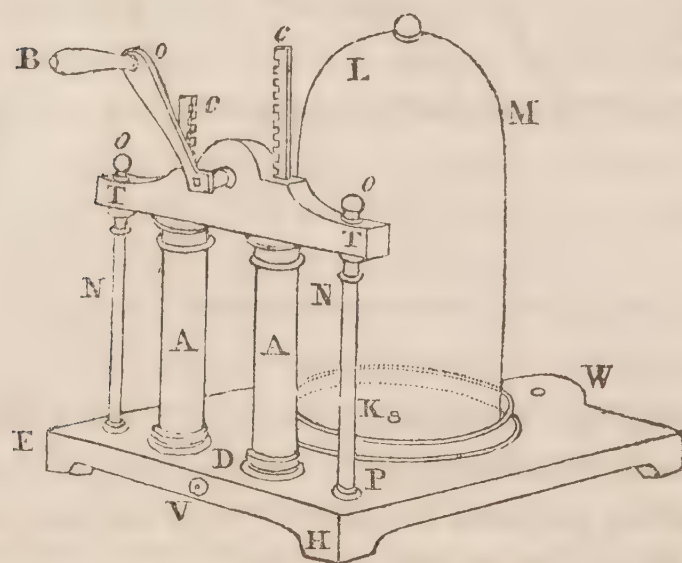
By sliding the receiver *a*, furnished with a bladder and stop-cock, from the shelf *b*, and pressing it into the trough, the air becomes transferred when the stop-cocks are opened into the bladder *c*.

POTASSIUM APPARATUS, Fig. 3, plate X.—
(See page 34.)

PRECIPITATING GLASS, figs. 5 and 6, plate XI., and figs. 8 and 9, plate XVI.—Are oval cylindrical glasses in which precipitations are performed, in order to collect the separated matter into less room. They are either cylindrical, and furnished like those represented figs. 8 and 9, which are also called decanting jars, or they are *conical*, as figs. 5 and 6, plate XI. They are furnished with lips for conveniently decanting the fluid from the precipitate at the bottom.

PUMP, PNEUMATIC.—The pneumatic or air-pump is one of the most useful of all philosophical instruments,

the actions of which depend on the mechanical properties of air. By the help of this machine the physical properties of air may be demonstrated in the most simple and elegant manner. Its construction is as follows : and will be obvious from the subjoined sketch, *E, G*, is a square table of



wood, *A A* are two strong barrels or tubes of brass, firmly retained in their position by the piece of wood *T T*, which is pressed on them by screws *o o*, fixed on the tops of the brass pillars *N N*. These barrels communicate with a cavity in the lower part or bed of *D*. At the bottom within each barrel is fixed a valve, opening upwards, and in each a piston works, having a valve likewise opening upwards. The pistons are moved by a cog-wheel in the piece *T T*, turning by the handle *B*, and whose teeth catch in the racks of the pistons *c c*. *P*, is a circular brass plate, ground perfectly smooth, having near its center the orifice *K* of a concealed pipe, that communicates with the cavity ; in the piece or bed of the pump *D* at *v*, is a screw that closes the orifice of another pipe, for the purpose of admitting the external air when

required. *L M*, is a glass receiver, out of which the air is to be exhausted. It is placed on the brass plate *p* slightly greased to prevent the air from insinuating itself under the edge of the glass receiver.

When the handle *B* is turned, one of the pistons in the barrel *A* is raised, and the other depressed; a void space is consequently left between the raised piston and the lower valve in the correspondent barrel; the air contained in the glass receiver *L M*, communicating with the barrel by the orifice *K*, on the ground brass plate, immediately raises the lower valve by its spring, and expands into the void space; and thus a part of the air in the receiver is extracted. The handle then being turned the contrary way, raises the other pistons, and performs the same act in its correspondent barrel; while in the mean time, the first mentioned piston being depressed, the air, by its elasticity closes the lower valve, and raising the valve in the piston, makes its escape. The motion of the handle being reversed, the first barrel again exhausts while the second discharges the air in its turn: and thus during the time the pump is worked, one barrel exhausts the air from the receiver, while the other discharges it through the valve in its piston.

Hence it is evident, that the vacuum in the receiver of the air-pump can never be perfect; that is, the air can never be entirely exhausted: for it is the spring of the air in the receiver that raises the valve, and forces air into the barrel, and the barrel at each exhaustion can only take away a certain part of the remaining air, which is in proportion to the quantity before the stroke, as the capacity of the barrel is to that of the barrel and receiver added into one sum.

This, however, is an imperfection that is seldom, if ever of any consequence in practice, because all air-pumps, at

a certain period of the exhaustion, cease to act, on account of their imperfect construction. For the valves usually consist of a piece of oiled bladder or varnished silk tied over a hole so that the air is at liberty to pass by lifting up the varnished silk or bladder, but cannot return again, and there will unavoidably be a small space left between the lower valve and the piston when down. Now, it will happen, when the air in the receiver is very rare, that its elasticity will not be strong enough to overcome the adhesion of the varnished silk or bladder, forming the lower valve, which consequently, will remain shut, and the exhaustion cannot proceed. Or, before this period, it may happen, that the air between the valves when the piston is up may be so small as to lie in the space between the two valves when the piston is down without being sufficiently condensed for its elasticity to overcome the adhesion of the varnished silk or bladder-valve, and the weight of the atmosphere that presses it: in this case the upper valve will remain shut, and the exhaustion cannot proceed. In the best constructed air-pumps these imperfections are in a great degree removed.

In measuring the exhaustion effected by the pump, there are two methods of proceeding. The one shews the density of the air left in the receiver *L M*, without regarding such vapours as may assume an elastic form in the vacuum: the other exhibits the elasticity of the air in the receiver, without showing whether it be permanently elastic air. The quantity of air is shewn by an instrument called the pear-gage. It consists of a glass vessel in the form of a pear, with graduations near its upper end, that denote certain known parts of its bulk. This is included in the receiver, together with a vessel of mercury, into which its mouth may be occasionally plunged. When the exhaustion is made, the pear-gage is plunged

into the mercury, and the external air admitted into the receiver. The mercury rises in the gage, and occupies the whole of its cavity, except a space at top, possessed by a bubble of air, whose magnitude is known from the graduations, and is in proportion to the whole contents of the gage, as the quantity of air in the exhausted receiver is to an equal volume of the common atmospherical air.

This gage would be accurate for all purposes, if it were not that most fluid or moist substances assume an elastic form, when the pressure of the atmosphere is removed. For this reason it seldom indicates the elasticity or actual pressure of the fluid remaining in the receiver. The barometer gage is used for this purpose. If a barometer be included beneath a receiver, the mercury will stand at the same height as in the open air; but when the receiver begins to be exhausted, the mercury will descend, and rest at a height which is in proportion to its former height as the spring of the remaining air is to its original spring or elasticity before the exhaustion. It is usual to say, the air is as many times rarer than the atmosphere, as the column it sustains is less than the height the mercury stands at in a detached barometer. On account of the inconvenience of including a barometer in a receiver, a tube of six or eight inches length is filled with mercury, and inverted in the same manner as the barometer. This being included, answers the same purpose, with no other difference than that the mercury does not begin to descend till about three-fourths of the air is exhausted. It is called the *short barometer gage*. Others place a tube, of a greater length than the barometer, with its lower end in a vessel of mercury, while its upper end communicates with the receiver. Here the mercury rises as the exhaustion proceeds, and the pressure of the remaining air is shewn

by the difference between its height and that of the barometer. This is called the *long barometer gage*.

These gages are not often constructed so as to answer the purpose of shewing the degree of exhaustion to a great degree. For the mercury, though at first boiled, to clear it of the air and moisture that adhere to it, and render it sensibly lighter, gradually becomes again contaminated by exposure to the air in the basin of either gage. They cannot therefore with strictness be compared to a good barometer in which this does not happen. If the tubes of the gages be less than half an inch in diameter, the mercury will be sensibly repelled downwards, so as to require a correction for the long gage when compared with a barometer, whose tube is of a different bore, and to render the short gage useless in great exhaustions. Thus, for example, if the short gage have a tube of one-tenth of an inch in diameter, the mercury will fall to the level of the basin when the exhaustion is 150 times, and will stand below the level for all greater degrees of rarefaction. These difficulties may all be removed, by making the short gage in the form of an inverted syphon, with one leg open, and the other hermetically sealed. It must be confessed, however, that it is not easy to boil the mercury in these; and the method of doing it with success cannot, with sufficient conciseness, be described here.

Few air-pumps exhaust to so great a degree as one thousand times by the barometer gage; but the *pear-gage* in some circumstances will indicate an exhaustion of many thousand times.

PYROMETER, (WEDGWOOD'S.)—Fig. 7, plate XIV. An instrument contrived for measuring the expansions and contractions of solid bodies by changes of temperature.

We shall here give an account of Wedgwood's pyrome-

ter, and subjoin a brief description of that constructed by Guyton.

A measure for the higher degrees of heat, such as the common thermometers afford for the lower ones, would be an important acquisition both to the philosopher and the practical artist. When we are told, for instance, that such and such materials were changed by fire into a fine white, yellow, green, or other coloured glass, and find that these effects do not happen, unless a particular degree of fire have fortunately been hit upon, which degree we cannot be sure of succeeding in again—when we are disappointed by having the result at some times an unvitrified mass, and at others an overvitrified scoria, from a little deficiency or excess of heat—when we see colours altered not only in shade but in kind, and in many cases destroyed by a small augmentation of the heat which had produced them, how much is it to be wished that the authors had been able to convey to us a measure of the heat made use of in their valuable processes!

Mr. Wedgwood, in a long course of experiments for the improvement of the manufacture he is engaged in, found some of his greatest difficulties to arise from not being able to ascertain the heat, to which the experiment-pieces had been exposed; and having no other resource, he was obliged at first to content himself with such measures as his own kilns and the different parts of them afforded. Thus the kiln in which his glazed ware is fired furnishes three measures, the bottom being of one heat, the middle of a greater, and the top still greater; the kiln in which the biscuit ware is fired, furnishes three or four others, of higher degrees of heat; and by these he marked his registered experiments. But these measures were neither fully adequate to his own views, nor capable of being communicated to others; their use is confined to a particular

structure of furnaces, and mode of firing, and upon any alteration in these, they would become useless and unintelligible, even where now they are best known. And indeed as this part of the operation is performed by workmen of the lowest class, it is impossible to depend upon any great accuracy even in one and the same furnace. It has accordingly often happened, that the pieces fired in the top of the kiln in one experiment have been made no hotter than those fired in the middle in another, and *vice versa*.

The force of fire, in its higher as well as lower stages, can no otherwise be justly ascertained than by its effects upon some known body. Mr. Wedgwood observed, that compositions of oxides of iron with clay assumed, from different degrees of fire, such a number of distinct colours and shades as promised to afford useful criteria of the respective degrees.

With this idea he prepared a quantity of such a composition, and formed it into circular pieces, about an inch in diameter, and a quarter of an inch thick. A number of these were placed in a kiln, in which the fire was gradually augmented, with as much uniformity and regularity as possible, for near sixty hours. The pieces taken out at equal intervals of time during this successive increase of heat, and piled in their order upon one another in a glass tube, exhibited a regular and pretty extensive series of colours; from a flesh colour to a deep brownish red, thence to chocolate, and so on nearly to black, with all the intermediate tints between these colours. A back being fixed to the tube, like the scale of a thermometer, and the number of the pieces marked upon it respectively opposite to them, it is obvious, that these numbers may be considered as so many thermometric divisions or degrees; and that if another piece of the same composition be fired

in any other kiln, or furnace, not exceeding the utmost heat of the first, it will acquire a colour corresponding to some of the pieces in the tube, and thus point out the degree of heat which that piece, and consequently such other matters as were in the fire along with it, have undergone.

It must, however, be confessed, that for general use, a thermometer on this principle is liable to objection, as ideas of colour are not perfectly communicable by words; nor are all eyes, or all light, equally adapted for distinguishing them, especially the shades which approach near to one another; and the effects of vapours in altering the colour, may not in all cases be easily guarded against.

In considering this subject attentively, another property of argillaceous bodies occurred to Mr. Wedgwood; viz. the diminution of their bulk by fire. This he found to be a more accurate and extensive measure of heat than the different shades of colour.

He found that this diminution takes place in a low red heat; and that it proceeds regularly, as the heat increases, till the clay becomes vitrified, and consequently to the utmost degree that crucibles or other vessels made of this material can support. The total contraction of some good clays, which he examined in the strongest of his own fires, is considerably more than one-fourth part in every dimension.

The contraction the clay suffers is permanent, or it does not return to its former dimensions when cold; the degree of contraction, therefore, can be ascertained without any fallacy from the existing temperature, and will indicate the extreme of temperature to which it has been exposed.

This pyrometer consists of a gage, fig. 7, plate XIV. composed of two straight pieces of brass, *a, b*, twenty-four inches long, divided into inches and tenths, and fixed on a brass plate, *c, d, e, f*, so as to converge; the space be-

tween them at the one extremity being five-tenths of an inch, and at the other three-tenths. The clay well washed is kneaded, and fashioned into small cylinders, flattened on one side, made in a mould, so as to be adapted exactly to the wider end, after having been heated to redness. It is evident, that in exposing one of these pieces to a high temperature, the contraction it has suffered may be measured by the length to which it can be slid in the converging groove*.

To add to the utility of this instrument, by connecting it with the mercurial thermometer, and by ascertaining the proportion between the degrees of each, Mr. Wedgwood made a series of experiments. The scale of his pyrometer commences at red-heat visible in day-light. The mercurial thermometer cannot easily measure any temperature above 500° or 550° . To measure the interval between the termination of the scale in the one and its commencement in the other, he employed the expansions of a square piece of silver, measured in a gage of earthenware, constructed in the same way as his pyrometer; and by the same method he found out the proportion between each degree of his scale, and the usual thermometrical scales. Each degree of his pyrometer he found to be equal to 130° of Fahrenheit. The commencement of his scale, or the point marked 0, corresponds with $1077\frac{1}{2}^{\circ}$ of Fahrenheit's scale. Hence it is easy to reduce either to the other, through their whole range. The scale of Wedgwood includes an extent of temperature equal to about 32000° of Fahr. or 54 times as much as that between the freezing and boiling points of mercury.† Its commencement is at $1077\frac{1}{2}^{\circ}$ of Fahr. or red-heat visible

* Philosophical Transactions, vol. lxxii. p. 310.

† Philosophical Transactions, vol. lxxiv. p. 310.

in day-light; its extremity is 240° ; but the highest heat that he measured with it is 160° , or $21,877^{\circ}$ of Fahr. this being the temperature of a small air-furnace, and 30° of the scale above the point at which cast-iron melts. Guyton has more lately affirmed, that the relation which Mr. Wedgwood assigned to the degrees in his scale, and those of the usual thermometrical scales, is altogether incorrect. Instead of each degree being equal to 130° of Fahr. scale, it is equal only to 62.5 : instead of 1077 of Fahr. corresponding in number with the commencement of Wedgwood's, 517 is the corresponding number; and of course all the higher parts of the pyrometrical scale indicate thermometrical degrees by far too great; the heat of a forge, for example, instead of being equal, as Wedgwood estimates it, to 17327 of Fahr. is equal only to 8696. The error, Guyton supposes to have arisen from Mr. Wedgwood having stated the fusibility of silver too high; instead of indicating 28° on his scale, as he determines it, it appears from all the experiments that have been made by others to be only 22° . That Wedgwood's degrees are actually stated too high in relation to the usual thermometrical scale, appears from some farther observations. Dr. Irvine, for example, from a number of trials, found reason to believe that the heat of a common fire is equal to about 790 of Fahr. while Wedgwood states red-heat visible in day-light, which must be rather below the other, at 1077. Guyton, however, reduces them too low: the commencement of Wedgwood's scale, denoted by red-heat, is certainly higher than 517° of Fahr., the number which Guyton assigns; for this temperature, and considerably beyond it, is measurable both by mercury and oil, neither of which sustains a red-heat.

A Pyrometer has been invented by Guyton for indicating high temperatures, in which platina is employed to measure the degrees of expansion. A rod or plate of this metal is placed horizontally in a groove, made in a mass of highly baked white clay; one extremity of the rod or plate is supported on the mass which terminates the groove; the other presses against a bended lever, of platina, the longest arm of which forms an index to a graduated arc. The expansion which the rod of metal undergoes by exposure to heat, is shewn by the changes in the position in this index. The mass of clay, having been previously hardened and contracted, by great heat, will not be liable to any important error from its contraction; and the alteration which it may suffer, during exposure to heat, will affect only the small distance between the axis of motion of the index, and the point of contact of the plate, so as rather to diminish the effect than to encrease it. Platina not being liable to chemical action on being heated, and being infusible at the highest heat which is required to be measured, it is well adapted to the construction of a Pyrometer.

Dr. Ure proposes a pyrometer capable of indicating high degrees of heat, by the expansion of air. As dry air has been found to increase in volume $\frac{3}{8}$ ths for 180 degrees of temperature, and as there is reason to believe that uniform increments of heat would occasion uniform degrees of expansion, the doctor recommends to form a bulb and tube of platinum, of exactly the same form as a thermometer, and connect with the extremity of the stem, at right angles, a glass tube of uniform calibre, filled with mercury, and terminating below in a recurved bulb, like that of the Italian barometer. Graduate the glass tube into a series of spaces, equivalent to $\frac{3}{8}$ ths of the total volume of the capacity of the platina bulb,

with $\frac{3}{4}$ ths of its stem. The other fourth may be supposed to be little influenced by the source of heat. On plunging the bulb and $\frac{2}{3}$ ds of the stem into a furnace, the depression of the mercury will indicate the degree of heat. As the movement of the column will be very considerable, it will be scarcely worth while to introduce any correction for the change of the initial volume by barometric variation. Or the instrument might be made with the recurved bulb sealed, as in professor Leslie's differential thermometers. The glass tube may be joined by fusion to the platinum tube. Care must be taken to let no mercury enter the platinum bulb. Should there be a mechanical difficulty in making a bulb of this metal, then a hollow cylinder of $\frac{1}{2}$ inch diameter with a platinum stem, like that of a tobacco-pipe screwed into it, will suit equally well.

A great number of Pyrometers of inferior importance have been invented, and ingeniously contrived for the purpose of measuring low degrees of temperature, by the expansion of metallic bars, &c. which are made to indicate changes by moving wheels, levers, and other mechanical contrivances.

RASPS are usually considered as requisite parts of the furniture of a Laboratory; the forms of those which are likely to be most useful are represented at fig. 3, and fig. 4, plate 2.

REFLECTORS (PICTET's) for experiments with radiant heat, fig. 10, Plate 14. These concave reflectors a, and b, are usually made of planished tinned iron plate, about 12 inches diameter, and segments of a sphere of nine inches radius; they must be fastened by sliding rings and screws on metallic stands c, c. To

show that invisible rays of heat are radiated from a hot body through space, and reflected from polished surfaces, as light is, let the two reflectors upon their stands be placed upon a table, about six feet apart, and exactly opposite to one another; let a heated ball *d*, be placed in the focus of the mirror *a*, there being a temporary screen of glass or paper interposed between them. In the focus of the reflector *b*, place an air thermometer, *e*, remove the screen from between the heated ball and the reflector *a*, and rays of heat will proceed from the ball in every direction, the mirror will receive some of them on every part of its surface, and the rays which fall upon it will be reflected in straight lines towards the mirror *b*, from the surface of which they will be again reflected, and made to converge to a focus upon the bulb of the air thermometer. The heat in the focus of these rays being considerable, the air within the bulb of the thermometer will be heated, and by its expansion, drive the liquid down to the bottom of the tube. Place the screen again between the ball *d*, and the mirror *a*, and the heat which affects the thermometer will be intercepted, the air will contract in bulk, and the liquid will rise again in the tube. A flask of hot water may be occasionally used instead of the heated ball.

A quantity of ice or snow in a glass vessel being substituted for the heated ball in the focus of the mirror *a*, radiation of heat will take place in the opposite direction; the bulb of the thermometer, in that case, being the hottest body, the air within the thermometer, losing its heat by this radiation, contracts in bulk and allows the liquid in the tube to rise higher up.

These mirrors may be used to illustrate the different radiating powers of different surfaces. For this purpose a canister of tinned iron plate, forming a cube of

about 6 inches, is generally used. The canister should have one side painted with lamp black, another should be scratched with sand paper, the third tarnished with quick silver, and the fourth should be left bright. When this canister is placed before the reflector *a*, instead of the heated ball, if the bright side be turned towards the reflector *a*, very little effect will be produced upon the air thermometer in the focus of the other reflector *c*, but if the black side of the canister be turned towards *a*, the thermometer in the focus of *b* will be heated, and the descent of the liquid will mark the difference. Intermediate degrees of effect may be produced by turning the other sides mentioned towards the reflector. By experiments like these, it is proved that polished metallic surfaces have least radiating power or in other words that they confine the heat most effectually, and that blackened surfaces have the greatest radiating power; or they are least capable of confining heat. These properties of black and of bright metallic surfaces may also be conveniently proved, by filling two tinned iron canisters of equal size, one black and the other bright, with boiling water; if the temperature of each vessel be tried by plunging the bulb of a thermometer into them, about ten minutes or a quarter of an hour afterwards, the water in the white vessel will be found considerably hotter than that in the black one, because the superior radiating power of the black vessel will enable the water which it contains, to cool much faster.

RECEIVER. SEE AIR JAR, page 32; BELL GLASS, page 53; and BALLOON, page 46.

RETORT. Retorts are made for various processes

in the arts of different metals, but those in common use are chiefly of glass or earthenware. They are either plain or tubulated; plain retorts are such as have no other opening beside that at the end of the tube. Plain retorts, to be convenient, should be rather wide in the neck or tube; they should be very thin at the part where heat is to be applied, that they may bear sudden changes of temperature without cracking; and, for some purposes to which they are applied, particularly when they are to be exhausted of air, they should be round and not flat at the bent part. Tubulated retorts have an opening at the bent part, supplied with a stopper for the convenience of charging them. Several representations of each kind may be seen in the plates. Retorts of green glass are found preferable for some experiments. Glass retorts require some management and care to prevent them from breaking; if any solid substance be put into a retort which adheres to the bottom of it when over a lamp, it is almost sure to break; if a retort be laid down while hot upon a substance capable of conducting away the heat from it rather quickly, there is almost a certainty that it will break; but it may be laid down upon a piece of woollen cloth, or on dry glass with safety.

SACHAROMETER, an instrument used by brewers for measuring the strength of wort, upon the principle of the Hydrometer already explained. Its name implies that it is an indicator of the quantity of sugar contained in the wort, but this name is incorrect, for it measures the whole quantity of solid substance dissolved in the water of which the wort is made. The instrument is composed of a large hollow bulb with a small heavy one under it, and a stem above the bulb with a gradu-

ated scale of an hundred equal parts upon it, commencing at the top. The weight of the instrument and the graduation of the scale, are so adjusted to one another, as to allow the stem to sink in distilled water, at the temperature of 70° , to the commencement of the scale; but when it is plunged into any liquor of the same temperature, the specific gravity of which is 1,100, it will sink only to the mark 100 upon the scale, which is just above the bulb.

Since the specific gravity of wort, which is intended for ale, is usually from about 1,090, to 1,100, and the specific gravity of wort for table beer from 1,020, to 1,030, it will be obvious that an instrument such as has been described, must be very useful and very effectual in ascertaining the required degrees of specific gravity.

SPIRIT LAMP, figs. 27, 28, plate I.—For chemical experiments upon a small scale, this is by far the most convenient kind of Lamp, as the flame of spirit of wine does not blacken, or in any degree, soil the vessel to which it is applied; and as the degree of heat may be regulated merely by raising the wick higher up, or by drawing it lower down. Any short, small glass bottle may be made to answer for a spirit lamp, but the shapes represented in the plate are those generally used, and in order to prevent waste of the spirit by evaporation, the lamp requires to have a glass cap fitted to it by grinding, so as to enclose the wick air tight.

STILL, METALLIC.—The distillatory apparatus used in experimental chemistry is mostly made of glass, but as small metallic stills are useful for some purposes, such as the distillation of water, they require to be described. The most usual form of metallic still is that which is represented, plate XII. fig. 1. The body or

boiler of the still *a*, and the head or capital *b*, are made of copper; the worm tub *c*, is of wood, and the worm *d*, of any convenient metal. The liquid which is to be converted into vapour is put into *a*, and made to boil by the application of heat; before the capital *b* becomes hot, a portion of the vapour will be condensed by the cold of its sides, but it is soon too much heated to condense the vapour; it then passes over into the refrigeratory or worm *d*, which is cooled by a quantity of cold water in the tube; this water receiving the heat which is set free by the vapour, when it condenses into a fluid, is rapidly heated, and requires to be changed when the distillation is continued for any length of time. The vapour arising from the still is thus condensed, by passing through the refrigeratory, and runs out in the fluid form at the end of the spiral pipe *e*, into the receiver *f*,—*g* is the stand upon which the worm tub is placed.

Distillation, upon a large scale, is performed in an apparatus very similar to that which has been described. The object of the distiller of spirituous liquors is to separate the alcohol, which has been previously formed by the process of fermentation, from the water with which it is mingled. The spirit of wine being more easily converted into vapour than the water, the vapour of the spirit rises first, and, being condensed by cold, is obtained in the liquid form. If it is desirable to encrease the strength of the spirit, by freeing it from more of the watery particles, that still adhere to it, this may be done by distilling it again. Great care is required to prevent loss of the spirit by evaporation, and also to prevent it from acquiring a disagreeable flavour in the process of distillation. A great number of different contrivances have been introduced into the construction of the still, another form of this apparatus may be seen, plate 13,

fig. 10, in which the condensing vessel is a cylinder instead of a spiral tube.

SYPHON. An instrument which is sometimes required to be used in the laboratory, for drawing fluids out of vessels that do not admit of being moved.

Different forms of this instrument may be seen at figs. 18 and 35, plate I, and fig. 7, plate II.—Where a tube of the form, fig. 35, is exhausted of air, by applying the mouth to the tube that is attached to the long side, the lower aperture being closed by a finger, or in any other way, and the aperture of the short side being immersed in water, the instrument is filled with water; and if the finger be then removed from the aperture of the long side, the water will flow out at that aperture as long as the short end is under the surface of the water in the vessel. The effect seems to depend partly upon gravity, and partly upon the pressure of air. When the finger is first removed, the water, yielding to the influence of gravitation, flows out, and this occasions the pressure to be removed from the inside of the tube, so that the pressure of the air on the outside, not being balanced within, causes the water to ascend and flow over, just as it would do if the tube were entirely exhausted of air.

SYPHON, (DR. URE'S) for the analysis of gaseous matter by explosion. It is thus described by the inventor. It consists of a glass syphon, having an interior diameter of from $\frac{2}{10}$ ths to $\frac{4}{10}$ ths of an inch. Its legs are of nearly equal length, each being from six to nine inches long. The open extremity is slightly funnel-shaped; the other is hermetically sealed; and has inserted near it, by the blow pipe, two platina wires. The outer end of one wire is incurvated across, so as nearly

to touch the edge of the aperture; that of the other is formed into a little hook, to allow a small spherical button to be attached to it, when the electrical spark is to be transmitted. The two legs of the syphon are from one-fourth to one-half inch asunder.

The sealed leg is graduated, by introducing successively equal weights of mercury from a measure glass tube. Seven ounces troy and 66 grains, occupy the space of a cubic inch; and 34 and $\frac{1}{4}$ grains represent $\frac{1}{1000}$ part of that volume. The other leg may be graduated also, though that is not necessary. The instrument is then finished.

To use it, we first fill the whole syphon with mercury or water, which a little practice will render easy. We then introduce into the open leg, plunged into a pneumatic trough, any convenient quantity of the gases, from a glass measure tube, containing them previously mixed in determinate proportions. Applying a finger to the orifice, we next remove it from the trough in which it stands like a simple tube; and by a little dexterity, we transfer the gas into the sealed leg of the syphon. When we conceive enough to have been passed up, we remove the finger, and next bring the mercury to a level in both legs, either by the addition of a few drops, or by the displacement of a portion, by thrusting down into it a small cylinder of wood. We now ascertain, by careful inspection, the volume of included gas. Applying the forefinger again to the orifice, so as also to touch the end of the platina wire, we then approach the pendent ball or button to the electrical machine, and transmit the spark. Even when the included gas is in considerable quantity, and of a strongly explosive power, we feel at the instant nothing but a slight push or pressure on the tip of the finger. After explosion, when condensation of volume

ensues, the finger will feel pressed down to the orifice by the superincumbent atmosphere. On gradually sliding the finger to one side and admitting the air, the mercurial column in the sealed leg will rise more or less above that in the other. We then pour in this liquid metal till the equilibrium be again restored, when we read off as before, without any reduction, the true resulting volume of gas.

As we ought always to leave two or more inches of air between the finger and the mercury, this atmospheric column serves as a perfect recoil spring, enabling us to explode very large quantities without any inconvenience or danger. The manipulation is, also, after a little practice, as easy as that of the single tube. But a peculiar advantage of this detachable instrument is, to enable us to keep our pneumatic troughs, and electrical machine, at any distance which convenience may require; even in different chambers, which, in the case of wet weather or damp apartment, may be found necessary to ensure electrical excitation. In the immediate vicinity of the water pneumatic cistern, we know how often the electric spark refuses to issue from a good electrophorus, or even a little machine. Besides, no discharging rod or communicating wire is here required. Holding the eudiometer in the left hand, we turn the handle of the machine, or lift the electrophorus plate with the right, and, approaching the little ball, the explosion ensues. The electrician is well aware that a spark so small as to excite no unpleasant feeling in the finger, is capable, when drawn off by a smooth ball, of inflaming combustible gas. Even this trifling circumstance may be obviated, by hanging on a slender wire instead of applying the finger.

We may analyze the residual gaseous matter by in-

roducing either a liquid or solid re-agent. We first fill the open leg nearly to the brim with quicksilver, and then place over it the substance whose action on the gas we wish to try. If liquid, it may be passed round into the sealed leg among the gas; but if solid fused potash, for example, the gas must be brought round into the open leg, its orifice having been previously closed with a cork or stopper. After a proper interval, the gas being transferred back into the graduated tube, the change of its volume may be accurately determined. With this eudiometer and a small mercurial pneumatic cistern, we may perform pneumatic analysis on a very considerable scale.

It may be desirable, in some cases, to have ready access to the graduated leg, in order to dry it speedily. This advantage is obtained, by closing the end of the syphon, not hermetically, but with a little brass cap screwed on, traversed vertically by a platina wire insulated in a bit of thermometer tube. After the apparatus has been charged with gas for explosion, we connect the spherical button with the top of the wire.

With the above instrument I have exploded half a cubic inch of hydrogen mixed with a quarter of a cubic inch of oxygen; as also, a bulk nearly equal of an olefiant gas explosive mixture, without any unpleasant concussion or noise; so completely does the air chamber abate the expansive violence, as well as the loudness of the report. Projection of the mercury, or displacement of the gas, is obviously impossible.—*Edin. Phil. Trans. January 1818.*

TEST TUBES are tubes of thin glass, from $\frac{1}{4}$ of an inch to $\frac{3}{4}$ of an inch in diameter, and from 2 inches to 6 inches in length; they are closed at one end by the blowpipe, and widened out into a lip at the open end. A

stand containing a number of these is represented, plate XVI. fig. 27. Tubes of this kind, are of the greatest use in experimental chemistry, for the examination of small portions of fluids, by tests or re-agents; they are also very convenient for holding small portions of fluids, while heat is applied to them, over the flame of a spirit lamp.

THERMOMETER. This instrument was originally invented in Italy, by Sanctorius, a physician, who lived in the seventeenth century; its form, as invented by that philosopher, is described at page 33, under the head **AIR THERMOMETER.** The members of the Academy del Cimento improved this instrument, by using a liquid instead of air as the measure of expansion. The liquid at first employed was coloured spirits of wine, which was inclosed in a tube hermetically sealed, to prevent injurious effects arising from variations of atmospheric pressure. Mercury was afterwards introduced as the best thermometric liquid, by Dr. Halley and Sir Isaac Newton. Mercurial thermometers are generally used, but spirit thermometers continue in use also, being most applicable to some particular purposes.

To construct a mercurial thermometer, a bulb is blown at one end of a glass tube having a very small bore; the bulb is then very much heated, and while it is hot, the open end of the instrument is immersed in a vessel of quicksilver; as soon as the expanded portion of air that remains within the instrument, cools and contracts, the pressure of air, on the outside of the quicksilver in the vessel, will force a considerable portion of that fluid to ascend into the instrument; but it cannot be sufficiently filled the first time of heating; it

must be again heated, and again immersed, until it is sufficiently filled. The bulb must then be heated once more, until the mercury expands so as to fill the tube entirely; at that moment, the flame of a lamp, urged by a blow-pipe, is directed upon the glass at the open part; it is melted, and hermetically sealed; when the mercury cools, it sinks down in the tube, and as no air can get in, it will be obvious, that the space left by the mercury, when it contracts by cooling, must be a vacuum. The next step in the progress of preparing the instrument is, to immerse it in dissolving ice or snow; when the mercury becomes stationary, a mark is made with a file upon the glass of the tube at that part; the instrument is then placed in water, which is made to boil, and as soon as the mercury becomes stationary again, another mark is made upon the glass at that part; the first mark indicates the freezing point; the second, the boiling point of water. By these or similar marks, the graduation of the scale, which is afterwards to be applied, must be regulated. If Fahrenheit's scale is to be applied, then there must be 180 equal parts or degrees, between the boiling and the freezing points, as marked upon the glass, and below the freezing point, there must be 32 more of the same equal divisions or degrees. From this point called zero, the divisions of the scale are numbered upwards, sometimes a little higher than 212, the boiling point of water, and sometimes rather higher than the boiling point of mercury, which is 655 degrees. It has generally been supposed, that the German artist, Fahrenheit, commenced his scale at the degree of cold produced by mixing snow and common salt, which was the lowest known in his time. But the temperature of snow and common salt, when mingled together, is 4 or 6 degrees

lower than the beginning of Fahrenheit's scale ; so that it is not now known, with certainty, in what manner he obtained the temperature with which his scale begins.

The scale of Reaumur commences at the freezing point of water which is marked 0, and is called Zero. The space between this point, and the boiling point of water, is divided into eighty equal parts or degrees. Since each degree on Fahrenheit's scale is equal to $\frac{4}{9}$ ths of a degree on Reaumur's, the correspondence between them may be found in the following manner : if the number of degrees on Fahrenheit's scale, either above or below the freezing point of water, be multiplied by 4, and divided by 9, the quotient will be the corresponding number on Reaumur's, to reduce those of Reaumur to those of Fahrenheit they must be multiplied by 9 and divided by 4.

The scale of the Centigrade Thermometer commences at the freezing point of water, between which and the boiling point are 100 equal divisions or degrees. One degree on Fahrenheit's scale, equals $\frac{5}{9}$ ths of one degree on the centigrade scale. To make the indications on the last mentioned scales correspond, the number of degrees of Fahrenheit above or below the freezing point of water, are to be multiplied by 5 and divided by 9. To reduce degrees on the centigrade scale to those of Fahrenheit, their number must be multiplied by 9 and divided by 5. The centigrade scale is much approved by some philosophers, but Fahrenheit's has one important advantage over it, in having its divisions much smaller ; on this account, fractional parts, which are often inconvenient, are the less requisite to be observed.

Dr. Murray was of opinion, that a thermometer with a scale, having the extreme points at the freezing and boiling of mercury, and 1000 equal divisions between, would be preferable to any of the thermometers in use.

The advantages of such a thermometer are thus described by Dr. Murray. The degrees would be smaller even than Fahrenheit's without being so much so as to be inconvenient, either in the construction of the instrument, or for observation; fractional parts might in general be entirely disregarded; and the commencement of the numeration being so low, we should scarcely ever have to express negative degrees. The commencement of the scale would also be about the lowest natural temperature. It seems the most natural method, too, to assume the freezing and boiling points of the fluid, which is the most accurate thermometrical one, and is most generally employed for that purpose, as the fixed points of the scale which its expansions are to measure. These points, by careful experiments, might be fixed with accuracy, and the degrees which correspond with the freezing and boiling points of water determined by actual trial; and this being done in the construction of the instrument, the common method might still be followed, though the scale might be divided and numbered in relation to the freezing and boiling points of quicksilver. Assuming the freezing and boiling points of quicksilver to be, according to Fahrenheit's scale, -40 , and $+655$; the freezing and boiling points of water are 99 and 347 on this new scale.

The advantages of mercury as a thermometric fluid, consist in its expanding more uniformly than alcohol; in its being more readily affected by changes of temperature, and it is capable of measuring higher degrees of temperature than any other fluid. As mercury does not boil until it is heated to 655 degrees of Fahrenheit's scale, and as it does not freeze until it is cooled to 39 degrees below zero of the same scale, it is capable of measuring changes of temperature, from 71 degrees

below the freezing point of water to 623 degrees above the same point. Alcohol is incapable of measuring changes of temperature above 182 degrees of Fahrenheit, being at that heat converted into vapour, but it is very useful in measuring changes below the freezing point of mercury, as it has not been frozen by any degree of cold yet produced.

Before the thermometer could be used with confidence as an indicator of changes of temperature, it was requisite that the expansions and contractions of the thermometrical fluid used, should be proved to correspond in every degree, with the addition or abstraction of temperature. If, by the addition of a certain quantity of caloric at a low temperature, a less or greater expansion is produced than by the same quantity of heat at a higher temperature, the instrument cannot be considered accurate. To investigate this point, the following experiment was made by several eminent philosophers. A thermometer, the tube of which was found to be perfectly cylindrical, was immersed in hot water, and the part of the tube where the fluid which it contained became stationary, was marked; the part was then marked at which the fluid became stationary when immersed in colder water; the next step was to mix the hot and cold fluids, in order to ascertain if the temperature of the two, when mixed, would be the mean between the different temperatures. But the correct mean temperature could not be attained. When a quantity of water, at 45 degrees, was mixed with an equal quantity at 200.7 degrees, the temperature of the mixture was 2.5 degrees less than the arithmetical mean, as indicated by a mercurial thermometer. From many similar experiments, similar results were obtained. In another experiment, the mercurial thermometer placed in a mixture of equal

parts of water at 32° and 212° indicated 119° instead of 122 , the mean temperature. Thermometers in which olive or linseed oils were used, gave indications still farther from the truth, standing at only 117° when plunged into a mixture of equal parts of water, at 32° and 212 ; a thermometer with alcohol plunged into a similar mixture indicated only 108° , and a thermometer containing water, as a measurer of expansion, gave only 75° instead of 122 , the real mean temperature.

De Luc has remarked upon the foregoing experiments, that they proceed upon the assumption that the capacity of water for caloric is permanent, within the range of temperature operated upon, while there is every probability that there is an increase of capacity, from augmentation of its temperature. This property, the capacity for caloric, is connected, to a certain extent, with the volume a body occupies; now, the expansion of water proceeding in an increasing ratio, the volume when two equal portions, at different temperatures, are mixed together, must be below the mean; there is accordingly, in mixing equal portions of water at 32° and 212° , a condensation of volume, equal to about 1.90th of its bulk. This is probably accompanied with a diminution of capacity, and from this cause a quantity of heat, must be given out in the experiment, which must raise the temperature above the true mean, or cause the resulting temperature to appear higher than it truly is. The extent of this, however, it is not easy to determine, as we do not know the relation between the change of volume and the change of capacity. It may therefore be trivial. To obviate this objection more clearly, Dr. Crawford farther made the experiment of exposing the thermometer equally to the influence of air, cooled by snow to 32° , and of air heated by steam to 212 , it rose

to 121° and remained stationary at that temperature fifteen minutes, the time during which the experiment was continued. It indicated, therefore, a temperature, one degree inferior to the arithmetical mean, when the difference of temperature amounted to 180° degrees. Even this deviation from the precise arithmetical mean he supposed to be diminished by admitting a correction for the effect of the temperature on the quantity of fluid in the stem of the thermometer. From these experiments this philosopher inferred that the mercurial thermometer is an accurate measure of heat, and also inferred from his experiments, combined with the other mode of experiment, that the capacity of water for caloric scarcely varies from 32° to 212° .

Mr. Dalton maintains, that water, mercury, and, in general, all pure homogenous liquids, notwithstanding the apparent diversity in their rate of expansion, expand according to the same law; the quantity of expansion being as the square of the temperature from their respective freezing points, or points of greatest density; and he recommends the graduation of a mercurial thermometer upon this principle. Such a thermometer would differ from the ordinary one with an equi-differential scale, by having its lower degrees smaller, and the upper ones larger; the mean between freezing and boiling water, or 122° on the new scale, will be found about 110° on the old one.

Respecting the principle of this thermometer, it has been asserted that it appears to rest more on analogy than on direct experiments, and it is considered hypothetical by some of the ablest chemists of the present age.

Of this, however, there appears to be no doubt, that the expansion of solid and fluid bodies is not equal for equal portions of heat applied to them; the first portion

of heat applied having a great force of attraction to overcome, produces the least effect ; the second portion having less attraction of cohesion to contend with, occasions a greater degree of expansion ; and on the same account every succeeding equal portion of heat produces an increased effect. “ Let 1000, says Dr. Ure, represent the cohesive attraction ; at the commencement, then, after receiving one increment of caloric, it will become $1000 - 1 = 999$. Since the next unit of that divellent agent will have to combat only this diminished cohesive force, it will produce an effect greater than the first in the proportion of 1000 to 999, and so on in continued progression.” This encreasing rate of expansion in fluids would certainly render the mercurial thermometer an incorrect indicator of changes of temperature, if the dilatation of the glass bulb and tube did not afford a compensation ; for as the fluid expands, the capacity of the bulb and tube enlarges also, just in that proportion which is required to counteract the unequable expansion of the fluid within. This important fact has been proved chiefly by the experiments of M. M. Dulong and Petit, who, taking advantage of the uniform expansion of air, used an air thermometer with which to compare the expansions of the mercurial thermometer, and the results of their experiments are expressed in the following table.

*Table of Comparison of the Mercurial and Air
Thermometer.*

Temperature indicated by the Mercurial.		Corresponding Vols. of the same mass of air.	Temperature indicated by an air ther. corrected for the dilatation of glass.	
Centigr.	Fahr.		Centigr.	Fahr.
— 36°	—32.8°	0.8650	—36.00°	—32.8°
0	+32	1.0000	0.00	+32.0
100	12	1.3750	100.00	212.0
150	02	1.5576	148.70	299.66
200	392	1.7389	197.05	386.69
250	482	1.9189	245.05	475.09
300	572	2.0976	292.70	558.86
Boiling 360	680	2.3125	350.00	662.00

We are justified, therefore, in considering a mercurial thermometer, that is skilfully made, a correct indicator of changes of temperature. Fig. 2, plate XIII. represents a mercurial thermometer, constructed in such a way, that the bulb may be immersed in any fluid to ascertain its temperature. Fig. 9, plate XIII. represents a thermometer graduated as high as the boiling point of mercury, having a part of the scale moveable to admit of the plunging of the bulb in any liquid.

To enable observers to register the various changes in the temperature of the air, several different thermometers have been invented. Six's thermometer, fig 9, plate XIV. has the bulb in the form of a long cylinder, the tube is bent down parallel with the cylinder and passing under it, rises in a parallel direction to the top on the other side; the bulb is usually filled with spirit of wine, which is in contact with a portion of mercury occupying the lower part of the tube, and the mercury is succeeded by a second portion of spirit. The mercury carries an index *a*, upon each of its surfaces; when

the fluid in the cylinder contracts, by cold, the index on the left side will be pressed upwards, as long as the heat decreases, and will be retained at its greatest height by a weak spring. When the fluid in the cylinder expands by heat, it must press upon the surface of the mercury in the left side of the tube, forcing it to rise higher in the right side: as long as the heat continues to increase, the index will rise on the surface of the mercury in the right side of the tube, and will be retained at the greatest height by its spring: it must be obvious, therefore, that the index on the side opposite the left hand will indicate the greatest degree of cold, in any given time, and the one on the right, the greatest degree of heat. The indexes being of iron or steel, may be brought back to their places by a magnet, applied to the outside of the tube.

The arrangement of thermometers by Rutherford is intended to answer a similar purpose. Two thermometers, with recurved bulbs, are placed horizontally in contrary directions, one containing mercury, and the other spirit of wine, fig. 5, plate X. One index is placed without the surface of the mercury, the other within that of the spirit of wine. Thermometers of this kind are now most frequently made with recurved bulbs of a cylindrical form.

Other self-registering thermometers have been invented, one of the most remarkable of which keeps an account of the variation of temperature for every instant of time, by describing a line on a revolving barrel. Another self-registering thermometer, the invention of Mr. Crichton of Glasgow, as described by Dr. Ure, consists of two oblong slips of steel and zinc, firmly fixed together by their faces; so that the greater expansion or contraction of the zinc, over those of the steel, by the

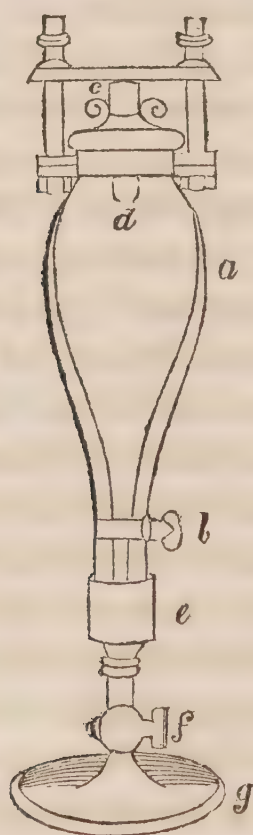
same variations of temperature, causes a flexure of the compound bar. As this bar is secured at one end to a board, the whole flexure is exercised at the other, on the short arm of a lever index, the free extremity of which moves along a graduated arc. The instrument is originally adjusted on a good mercurial thermometer; and the movements of the arm are registered by two fine wires, which are pushed before it, and remain at the maximum deviation to the right or left of the last observed position or temperature. The principle is the same as that of Arnold's compensation balance for Chronometers.

M. Brequet has constructed an extremely delicate instrument upon the same principle. It consists of a narrow metallic slip about $\frac{1}{100}$ th part of an inch thick, composed of silver and platina, soldered together; and it is coiled in a cylindrical form. The top of this spiral tube is suspended by a brass arm, and the bottom carries, in a horizontal position, a very delicate golden needle, which traverses as an index, on a graduated circular plate, a steel stud, rises in the centre of the tube, to prevent its oscillations from the central position. If the silver be on the outside of the spiral, then the influence of increased temperature will increase the curvature, and move the appended needle in the direction of the coil; while the action of cold will relax the coil, and move the needle in the opposite direction.

WATER (apparatus for the composition of) the contrivances for this purpose are numerous. The most simple is the detonating tube, fig. 54. plate 1. This tube being charged with two parts by bulk, of pure hydrogen, and one part of pure oxygen, over water, in the hydro-pneumatic trough, an electrical spark, passed through by

the wires near the top, will inflame the gases; they will combine with a flash of light, and instantly disappear, while the tube is filled with water from the trough. But this form of the experiment shews only the condensation, and not the minute quantity of water formed by the union of the gases.

The apparatus called Cavendish's (that philosopher having first successfully examined this subject,) affords an opportunity of performing this experiment more successfully. The following wood-cut represents this apparatus.

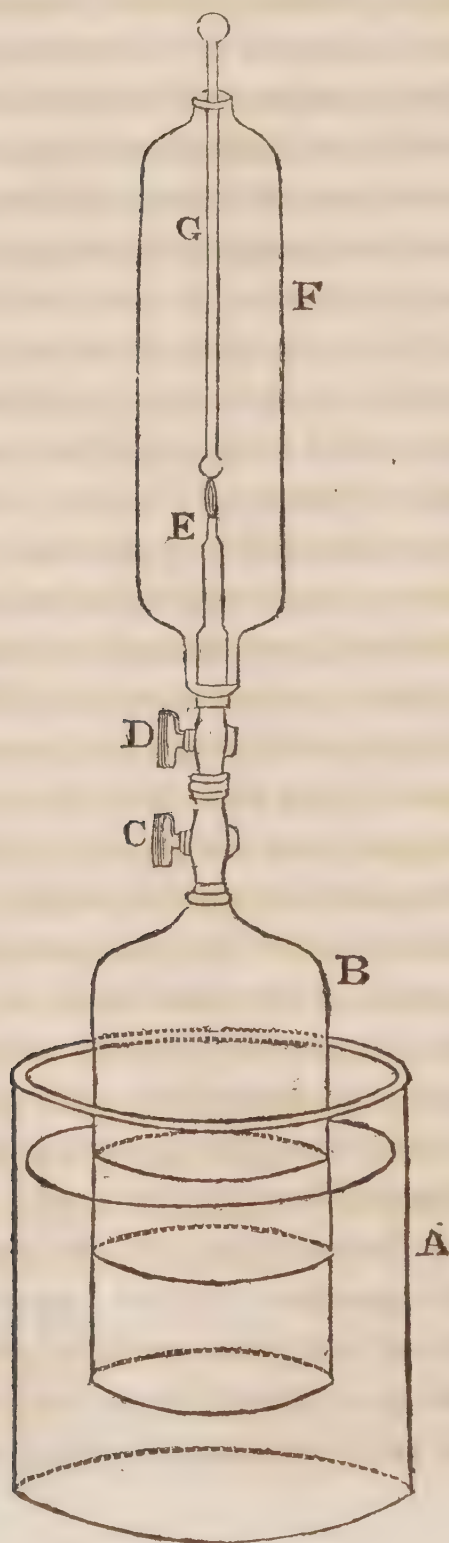


It is composed of a very thick glass vessel *a*, with a glass stopcock *b*, and a ground glass stopper *c*, which has two platinum wires *d*, passing through it, into the

inside of the vessel. There is also a collar of brass round the neck of the thick glass vessel, with two brass rods passing through it, for the purpose of receiving a bar of the same metal, the intention of which is to keep down the stopper, when gases are exploded in the inside. The bar is secured by a screw upon the end of each rod. A brass cap *e*, receives the lower part of the glass vessel, which is firmly fixed into it with cement; *f* is a brass stopcock which admits of being unscrewed at the brass cap above or at the brass foot below. To use this apparatus it is first to be unscrewed from the brass foot, and attached to the plate of an air pump, or to an exhausting syringe, that it may be exhausted of air; it must then be screwed to the top of an air jar, standing upon the shelf of a pneumatic trough, and containing a mixture of one volume of oxygen and two volumes of hydrogen; as soon as a communication is made between the exhausted vessel, by opening the glass stopcock *e*, and the brass one *f*, the gas rushes up and fills the vessel; it is then disengaged from the jar and screwed to its foot again. A chain is then hooked to the wire on one side of the glass stopper, and the operator, taking in his hand a small jar previously charged by being held in contact with the conductor of the electrical machine, and holding the end of the chain in the same hand, so that it may be in contact with the outside metallic coating of the jar, the brass knob of the jar is then made to touch the wire on the other side of the glass stopper; this occasions the jar to be discharged through the gases, which instantly combine with a flash of light, and the inside of the vessel is covered with moisture. If the apparatus be now attached to the air jar again, and the communication between them be opened, another quantity of air will rush in to fill up the void occasioned by the combination of the

gases, and this may also be inflamed by passing the electrical spark as before, with the same result.

The apparatus represented by the next wood cut, is



very convenient for shewing the formation of water, by burning a current of hydrogen in an atmosphere of oxygen. A is a glass jar containing water; B is a receiver filled with hydrogen; C and D are two brass stopcocks; E is a jet pipe where the hydrogen is inflamed; F is a cylindrical glass vessel exhausted of common air and filled with oxygen gas; G is a platinum wire with a ball at each end, by which the electrical spark is applied to inflame the hydrogen. On slightly pressing down the jar filled with hydrogen into the water, at the same time opening the stopcocks C and D, the gas ascends and is instantly inflamed by the electrical spark, and burns with great heat, while the water collects rapidly into drops, which will be seen trickling down on the inside of the glass cylinder.

But if it should be desired to perform this interesting experiment upon a larger scale, and with greater accuracy, other forms of apparatus must be adopted. Fig. 3, plate 5, represents an apparatus which has been used for the production of considerable quantities of water; *a a* are tubes communicating with the gassholder for the supply of oxygen and hydrogen gases; *b* is an exhausted glass vessel of a globular shape, in which the combustion is carried on; *c*, a tube for carrying off the water formed by the combustion; *d*, a brass plate perforated by the tubes *a a*, and the wires *e*,—*f* the points of the wires by which the electrical spark is communicated. The apparatus called Cuthbertson's, is admirably adapted for this experiment, figs. 30 and 31, plate 1. It consists of a large globular receiver, open at the bottom to admit a piece of brass with two apertures, such as is represented on a larger scale, at fig. 31: the oxygen gas enters by the aperture *a*, and the hydrogen by the aperture *b*, from two gasometers. The directions given by Dr. Henry for

composing water with this apparatus, are very clear and at the same time concise. “ When it is intended to ascertain accurately the proportions of gases consumed, and of water generated, the receiver *a*, previously weighed, is first exhausted by an air-pump, with which it may be connected by the female screw at *c*, fig. 30. The quantity of common air left in the receiver, may be determined by enclosing a guage within it. If the additional expense be not deemed an objection, it is adviseable, that after exhausting the receiver, oxygen gas should be admitted, its contents should be exhausted a second time, and again renewed by fresh oxygen from the gasometer, the quantity of which may be observed by the graduated scale. The receiver being thus filled with oxygen gas, and accurately closed by a cock at *c*, a succession of sparks is to be passed, from the prime conductor of an electrical machine, between the platina knob of the bent wire within the receiver, and the point of the brass cone. While the sparks are transmitted, the cock *d* is to be opened. A stream of hydrogen gas will immediately issue from the aperture at the point of the cone, and will be inflamed by the electric spark, as represented fig. 31. The cock *e* is now to be opened, and the size of the flame of hydrogen gas moderated by partly shutting the cock *d*. As the volume of hydrogen gas consumed is double that of the oxygen, and the pipe which transmits it, is of less diameter than that conveying the latter, about twice the pressure is required to expel the hydrogen. This is given, by lessening, in that proportion, the weight of the counterpoises of the gasometer containing hydrogen.

During the combustion, the moveable vessel of each gasometer descends; and by observing the graduated scales, it will be seen that the hydrogen vessel falls twice

as quick as that which holds the oxygen gas. It is necessary to keep the receiver *d* cool by means of wet cloths, and when this is done, the water which is produced will form into drops on the inside of the receiver, and collect at the bottom. At the conclusion of this experiment the receiver is to be again weighed, and the increase noted. The quantity of gases consumed is to be observed, and their actual weight computed. It will be found, that the weight of water produced is very nearly equal to that of the two gases expended; that is to say, for every hundred grains of water generated in the receiver, 88.3 grains of oxygen gas, and 11.7 grains of hydrogen gas (equal by measure to about 250 cubic inches of the former and 500 of the latter), will have disappeared from the gasometers."

WATER—DECOMPOSING APPARATUS. (See GUN-BARREL APPARATUS, page 164.)

WELTER'S SAFETY TUBE—Is a contrivance for preventing the bursting of distillatory apparatus, in consequence of the sudden extrication or condensation of any gaseous body during chemical processes, figs. 40 and 41, plate 1.

WOLLASTON'S (DR.) SCALE OF CHEMICAL EQUIVALENTS—The invention of this scale was made known in the first part of the Philosophical Transactions for 1814. It is a sliding scale intended to answer at sight an indefinite number of questions, respecting the composition and mutual decomposition of neutral salts; and is calculated to facilitate the study and practice of chemistry. It gives the composition of any weight whatever of any of the salts contained on the

scale, the quantity of any other salt necessary to decompose it, the quantity of new salt that will be formed, and many other similar things, which are perpetually occurring to the practical chemist, and cannot be answered without an arithmetical calculation.

The following extract from Dr. Wollaston's Paper will best describe the use of this important instrument.

“ It is not my design in the table which follows this paper, to attempt a complete enumeration of all those elements or compounds which I suppose to be well ascertained, but merely to include some of those which most frequently occur. I do not offer it as an attempt to correct the estimates that have been formed by others, but as a method in which their results may be advantageously applied in forming an easy approximation to any object of our enquiries.

The means by which this is effected may be in part understood by inspection of the Plate, (Plate 17,) in which will be seen the list of substances intended to be estimated, arranged on one or the other side of a scale of numbers in the order of their relative weights, and at such distances from each other, according to their weights, that the series of numbers placed on a sliding scale can at pleasure be moved, so that any number expressing the weight of a compound may be brought to correspond with the place of that compound in the adjacent column. The arrangement is then such, that the weight of any ingredient in its composition, of any reagent to be employed, or precipitate that might be obtained in its analysis, will be found opposite to the point at which its respective name is placed.

In order to show more clearly the use of this scale, the plate, (Plate 17) exhibits two different situations of the slider, in one of which oxygen is 10, and other bodies

are in their due proportion to it, so that carbonic acid being 27.54, and lime 35.46, carbonate of lime is placed at 63.

In the second figure, the slider is represented drawn upwards till 100 corresponds to muriate of soda, and accordingly the scale then shows how much of each substance, contained in the table, is equivalent to 100 of common salt. It shews with regard to the different views of the analysis of this salt, that it contains 46.6 dry muriatic acid, and 53.4 of soda, or 39.8 sodium, and 13.6 oxygen; or if viewed as chloride of sodium, that it contains 60.2 chlorine and 39.8 sodium. With respect to reagents, it may be seen that 283 nitrate of lead, containing 191 of litharge, employed to separate the muriatic acid, would yield a precipitate of 237 muriate of lead, and that there would then remain in solution nearly 146 nitrate of soda. It may at the same time be seen, that the acid in this quantity of salt would serve to make 232 corrosive sublimate, containing 185.5 red oxide of mercury, or would make 91.5 muriate of ammonia composed of 6 muriatic gas (or hydro-muriatic acid) and 29.5 ammonia. The scale shews also, that for the purpose of obtaining the whole of the acid in distillation, the quantity of oil of vitriol required is nearly 84, and that the residuum of this distillation would be 122 dry sulphate of soda, from which might be obtained, by crystallization, 277 of Glauber salt containing 155 water of crystallization. These and many more such answers appear at once by inspection, as soon as the weight of any substance intended for examination is made by the motion of the slider correctly to correspond with its place in the adjacent column.

With respect to the method of laying down the divisions of this scale, those who are accustomed to the use

of other sliding rules, and are practically acquainted with their properties, will recognise upon the slider itself, the common Gunter's line of numbers (as it is termed,) and will be satisfied that the results which it gives are the same that would be obtained by arithmetical computation.

Those who are acquainted with the doctrine of ratios, and with the use of logarithms as measures of ratios, will understand the principle upon which this scale is founded, and will not need to be told that all the divisions are logometric, and consequently that the mechanical addition and subtraction of ratios here performed by juxta-position, corresponds in effect to the multiplication and division of the numbers by which those ratios are expressed in common arithmetical notation.

To others who are not equally conversant with the nature of logarithms, and consequently have not so correct a conception of the magnitudes of ratios, some further explanation of the mode in which the scale of equivalents is constructed, will, I presume, be acceptable.

They will observe, that the series of natural numbers are not placed at equal intervals on the scale; but that at all equal intervals are found numbers which bear the same proportion to each other. In fig 3, plate 17, some of the larger intervals alone are represented on a line similarly divided. The succession of intervals, marked A, B, C, D, E, are all equal, and at these points of divisions are placed numbers, 1, 2, 4, 8, 16, which increase progressively by the same ratio. And since the series 3 : 6 : 12 : 24, increase in the same ratio of 1 to 2, these intervals (plate 17, fig 3) *a, b, c, d, e*, are the same as the former. At another succession of different yet equal intervals, marked F, G, H, I, are placed numbers 1, 3, 9, 27, which increase regularly by an equal ratio of 1 to 3;

and by means of a pair of compasses it would be found that the interval from 2 to 6, or from 6 to 18 (which are in the same ratio of 1 to 3) is exactly equal to F, G, the interval between 1 and 3. As any single space represents any one ratio, so the sum of any two or three equal spaces represent a double or triple ratio. If 1 be increased three times by the ratio of 1 to 2, it becomes 8, which bears to 1 triple the ratio of 2 to 1. This ratio is therefore rightly represented by A, D, which is the triple of A, B.

The distances of the intermediate numbers 5, 7, 10, 11, 13, &c. from 1, are likewise made proportional to the ratios which they bear to 1, and are easily laid down by means of a table of logarithms; for as these are arithmetic measures of the ratios which all numbers bear to unity, the spaces proportional to them become linear representations of the same quantities.

As the entire spaces A D, A E, represent the ratios of 8 and of 16 respectively to one, so the difference D E represents the ratio of 8 and 16, which stand at D and E, to each other. And in the same manner, any other space, *k*, *l*, represents correctly the ratio of 7 to 13; so that the measure of a fraction expressed by quantities that are incommensurate, is rendered as obvious to sight as any simple multiple. And if a pair of compasses be opened to this interval, and transferred to any other part of the scale, the points of the compasses will be found to rest upon numbers bearing the same proportion to each other as those from which the interval was transferred.

It is exactly in this manner that the various points in the column of equivalents indicate the several quantities sought in any given position of the slider. The relative distances at which the articles are placed, represent so many different openings of the compasses rendered per-

manent and presented to view at once. In the table which I shall place at the end of this communication, the relation of the various substances enumerated to each other is expressed by numbers. In the engraved scale of equivalents, the ratios of these numbers are represented by logometric intervals, at which they are placed, their several positions being determined by those of their respective numbers on the slider, which is logometrically divided. Consequently all the several points in the column of equivalents will indicate numbers in the same due proportions to each other, whatever part of the scale may be presented to them. Those who seek information, may obtain it by inspection; those who already possess it, may be able to correct the positions of some articles by direct comparison with the best analyses upon record, in whatever numbers the results of those analyses may happen to be expressed.

Another example will farther illustrate the application of this scale. Let us suppose that, in trying the strength of muriatic acid, 94 grains of carbonate of lime have been dissolved by the acid. Then if 94 upon the slider be set exactly to carbonate of lime, it may be seen that the solution would yield 104 muriate of lime, consisting of 53 lime, combined with 51 muriatic acid, which has disengaged 41 of carbonic acid. The quantities of other acids equivalent to 51 of muriatic acid, and of other bases equivalent to 53 of lime, appear by inspection at the same time, and also the weights of various neutral compounds that result from their union, and are therefore equivalents in mutual decomposition. It will be seen that to precipitate the muriatic acid by lead, we may take a solution of 310 nitrate of lead, 209 litharge, combined with 101 nitric acid, and shall then obtain 260 muriate of lead: that to precipitate the lime, we may use 89 pure

potash, and that there will then be in solution 140 muriate of potash; or, if we employ sulphate of soda, 303 of the crystallized salt will precipitate 162 selenite, and leave in solution 110 muriate of soda; with a great variety of similar information at once presented to view, in the same position of the slider.

THE END.

ERRATA.

- Page 30, line 13, for *Chevix*, read *Chenevix*.
.. 49, .. 32, omit *fig. 23, plate 15, x fig. 7, plate 7*.
.. 65, .. 17, for *produce*, read *produces*.
.. 68, .. 12, for *copper, copper*, read *copper*.
.. 71, .. 4, for *projeeting*, read *projection*.
.. 73, .. 32, for *fluxible*, read *flexible*.
.. 81, .. 15, for *mors*, read *more*.
.. 88, .. 31, for *fig. 28, plate 4*, read *fig. 54, plate 1*.
.. 120, .. 4, for *ammoniac*, read *ammonia*.
.. 122, .. 24, for *fig. 12, plate 12*, read *fig. 9, plate 12*.
.. 133, .. 4, for *fig. 1*, read *fig. 15*.
.. 134, .. 8, for *figs. 10 and 16*, read *figs. 10 and 11*.
.. 137, .. 29, for *fig. 9, plate 7*, read *fig. 11, plate 13*.
.. 143, .. 13, for *fig. 1*, read *fig. 11*.
.. 237, .. 10, for *chambers*, read *chamber*.
.. .. 13, for *cock*, read *cork*.

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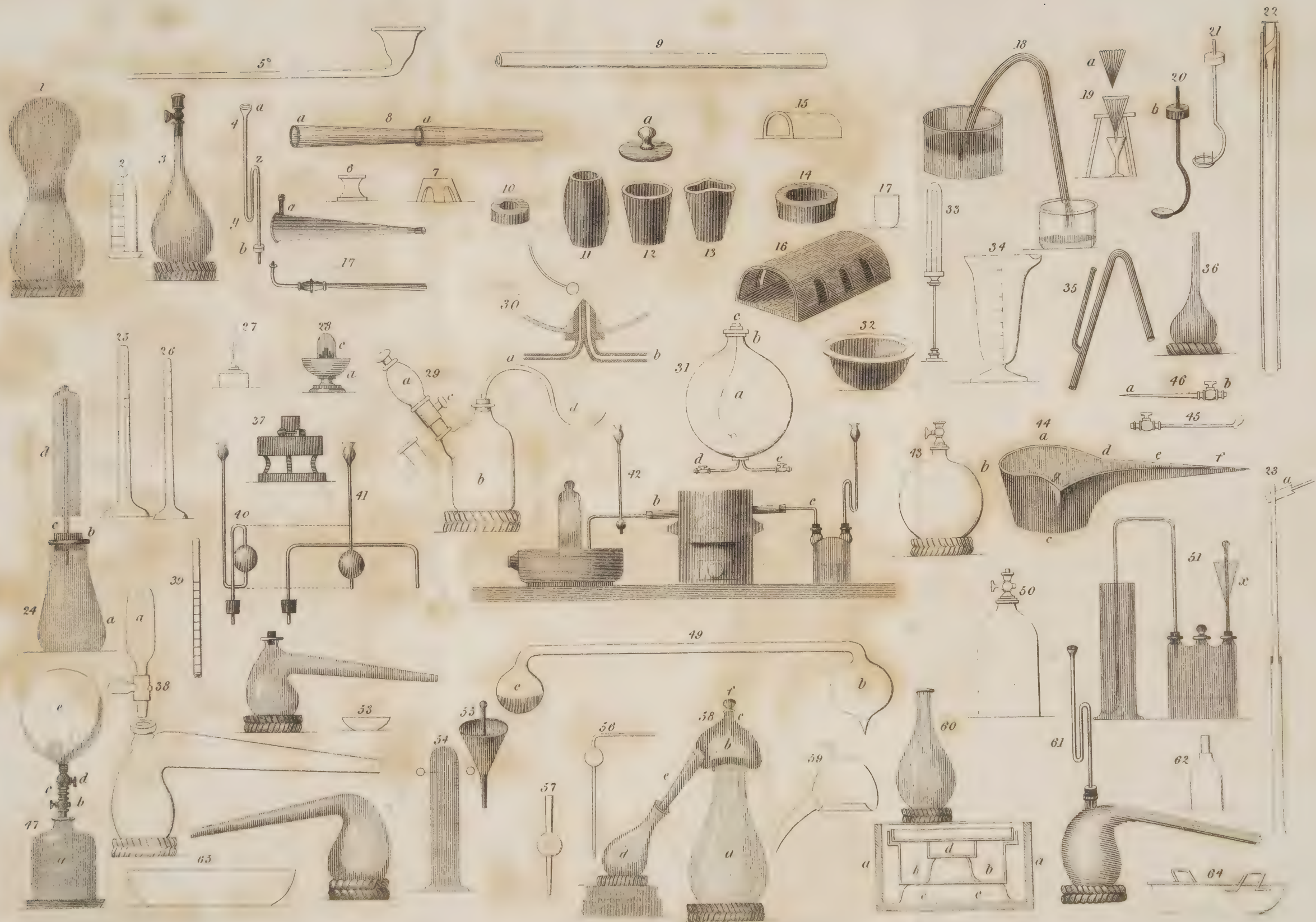
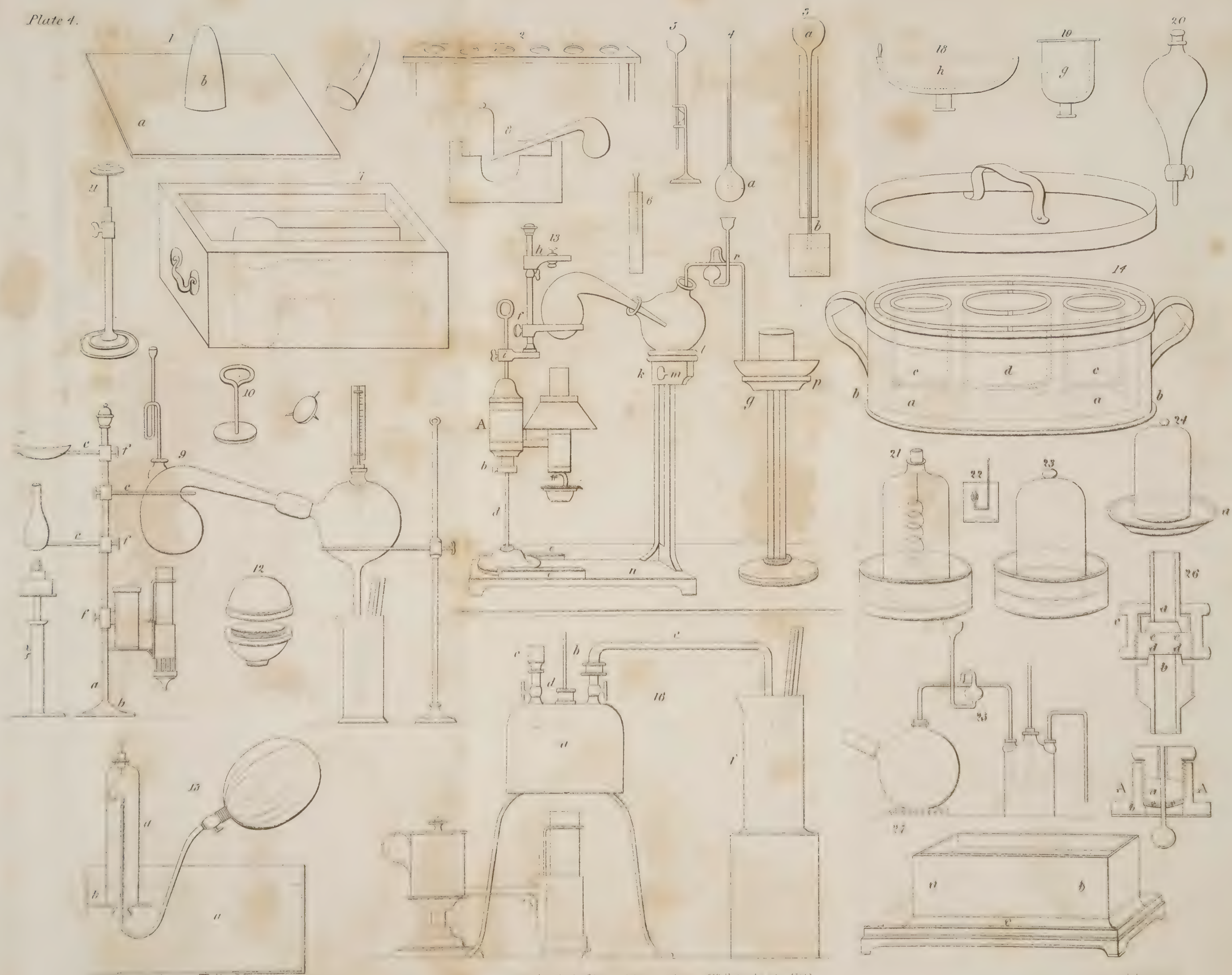


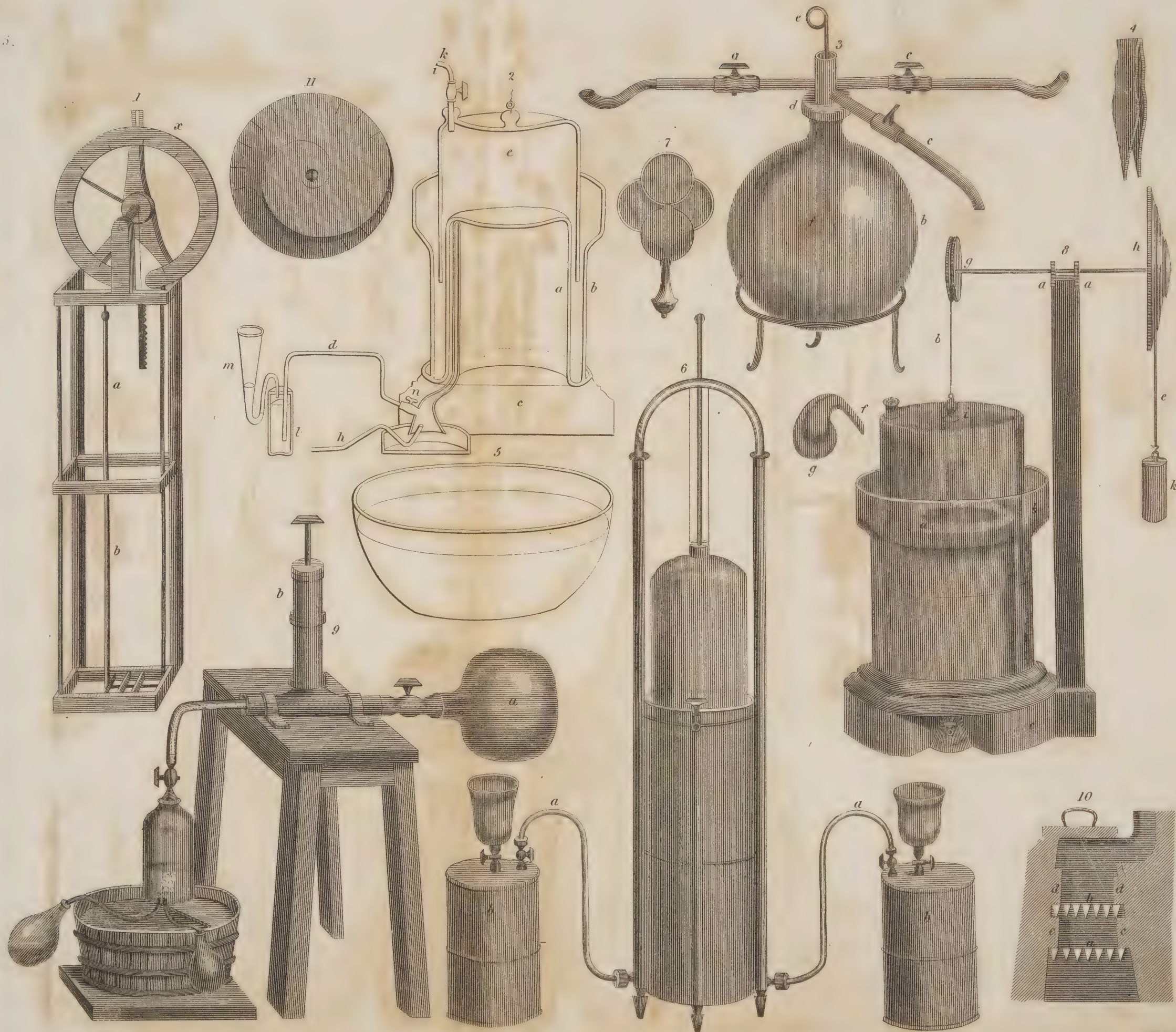


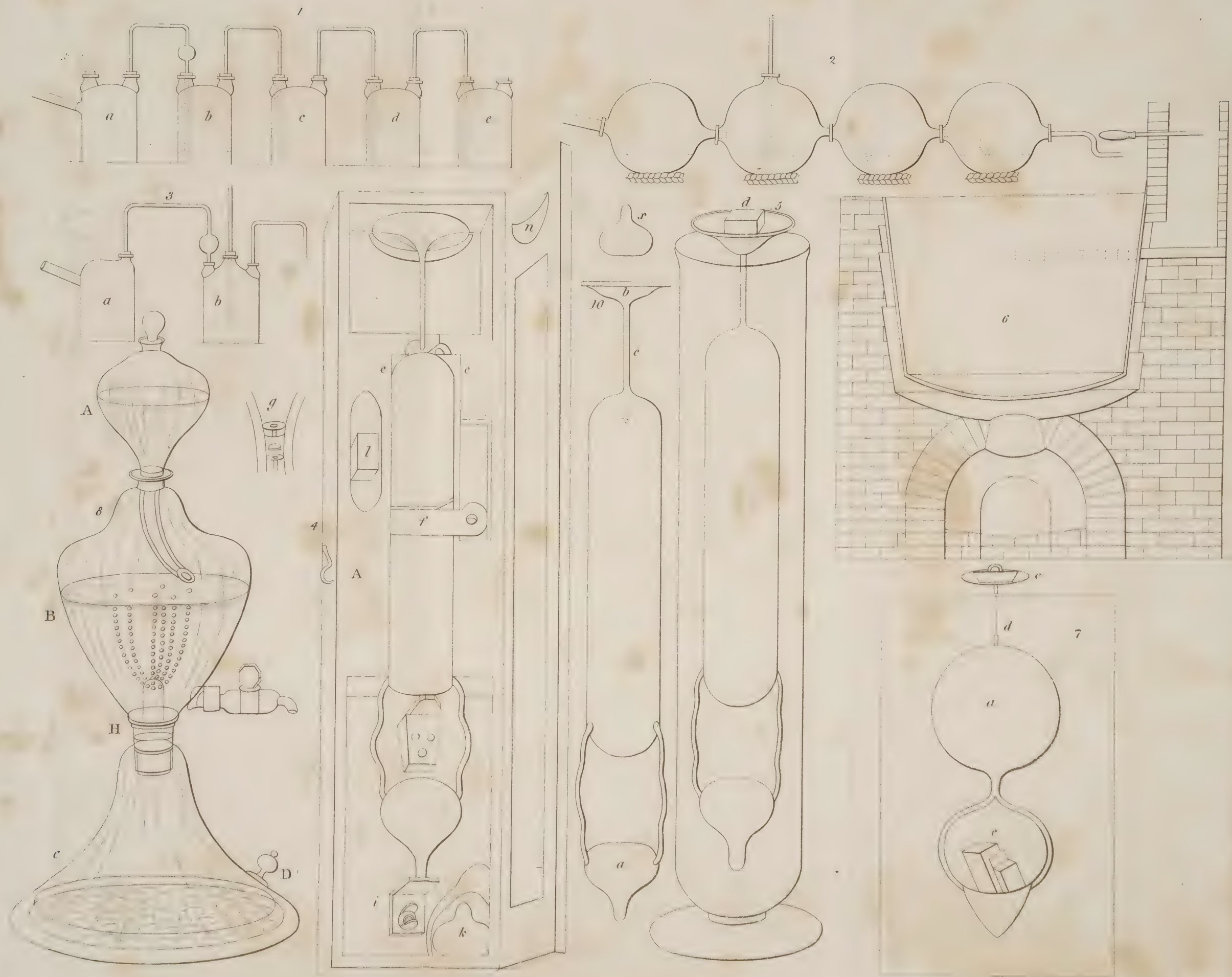




Plate 4.











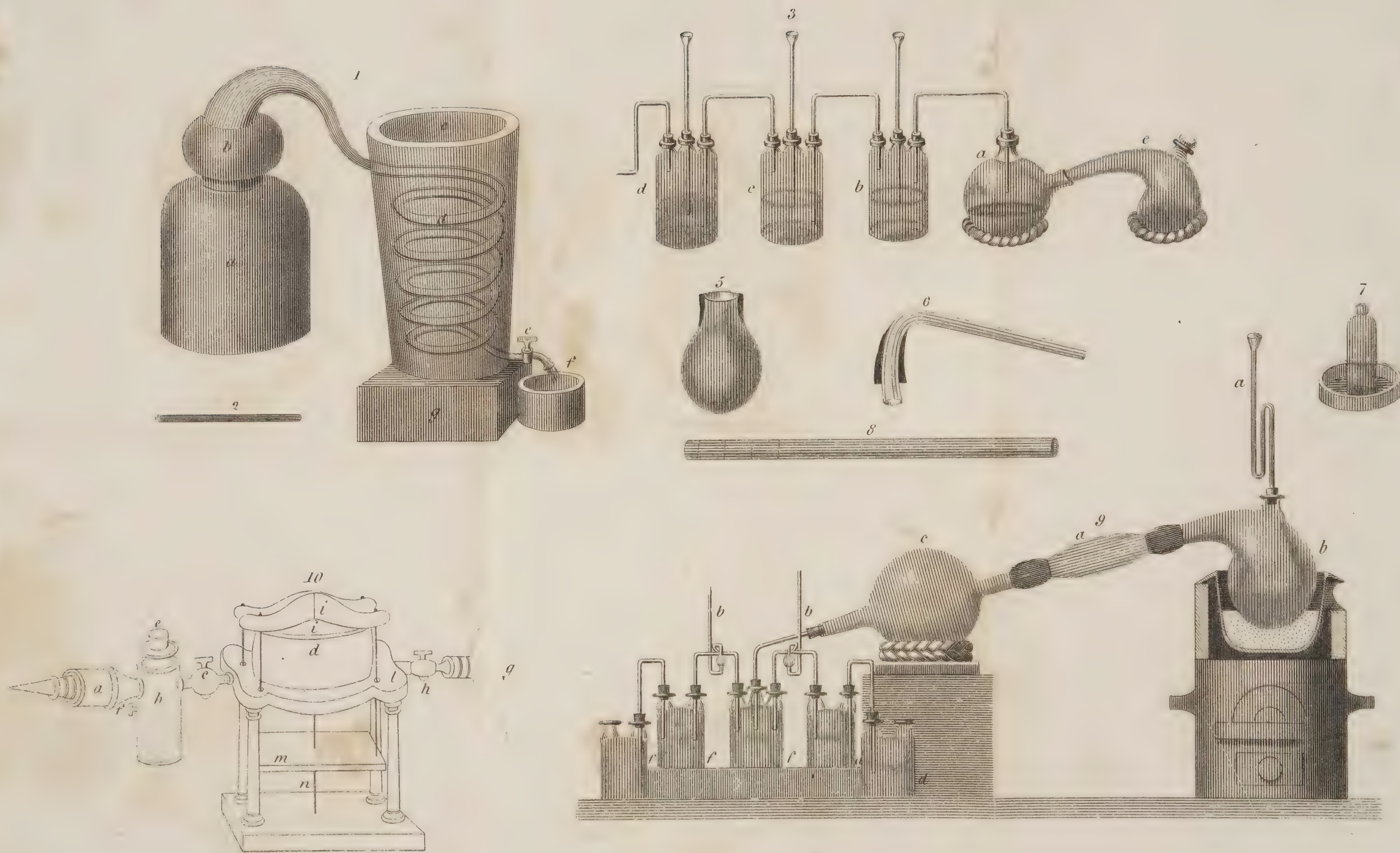


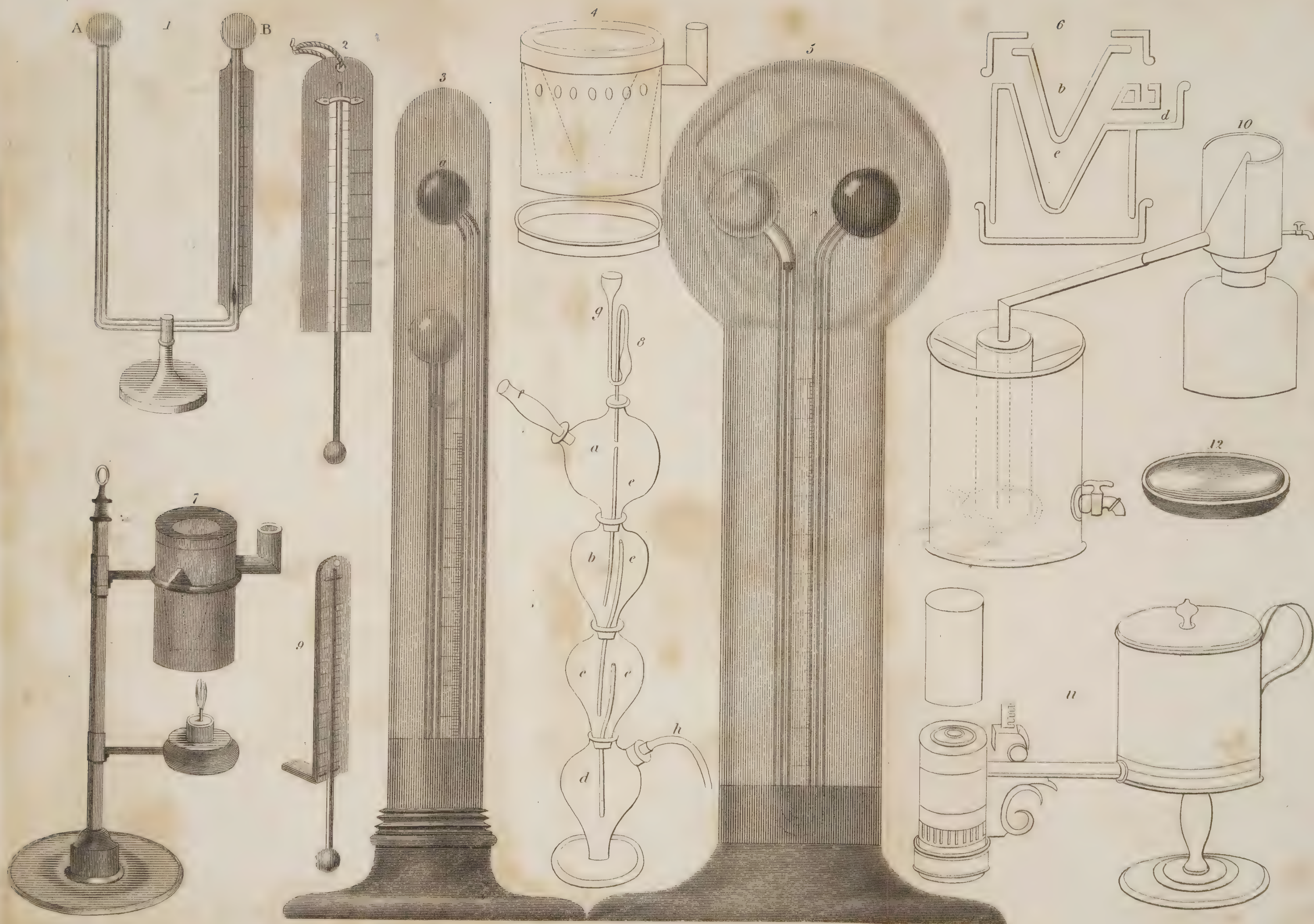


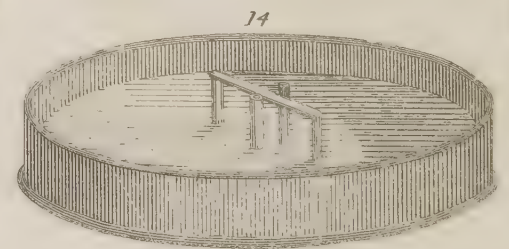
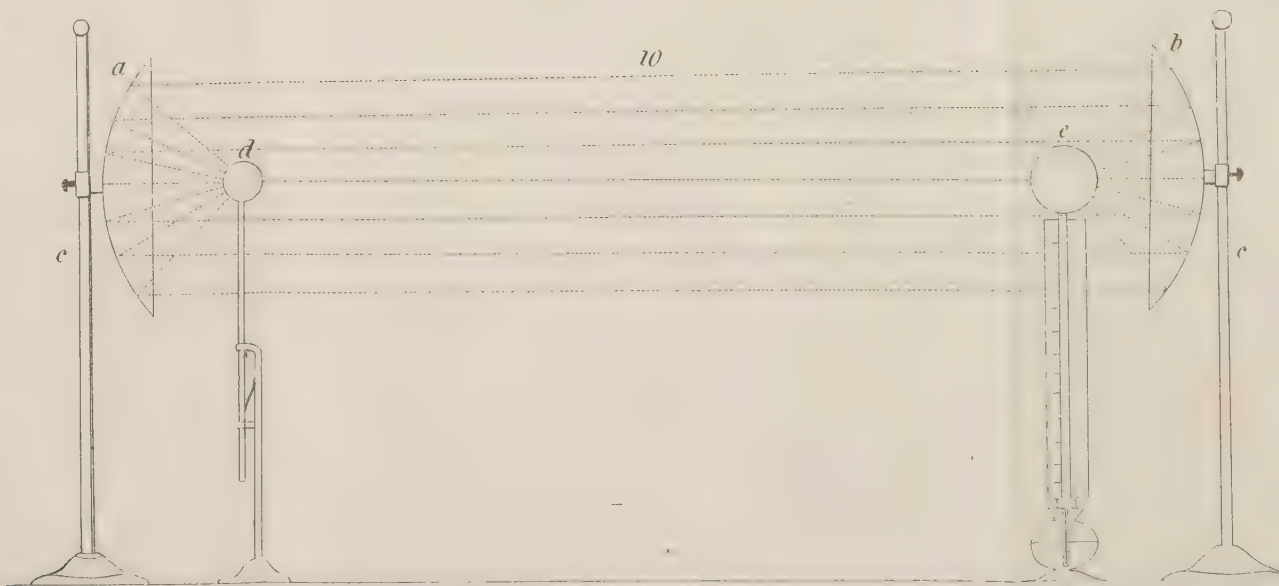
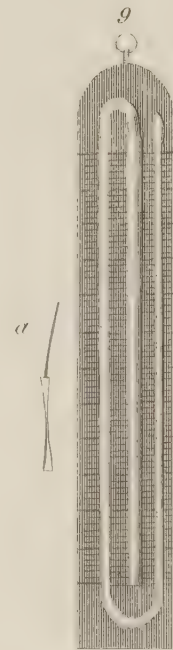
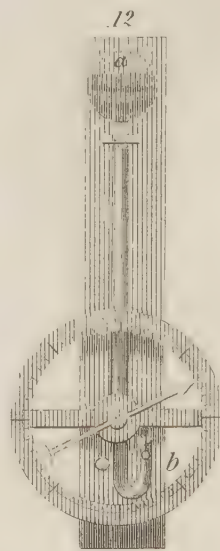
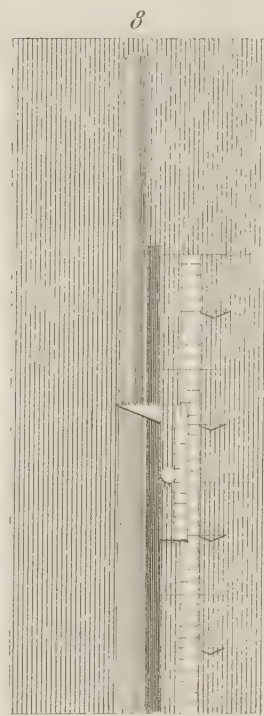
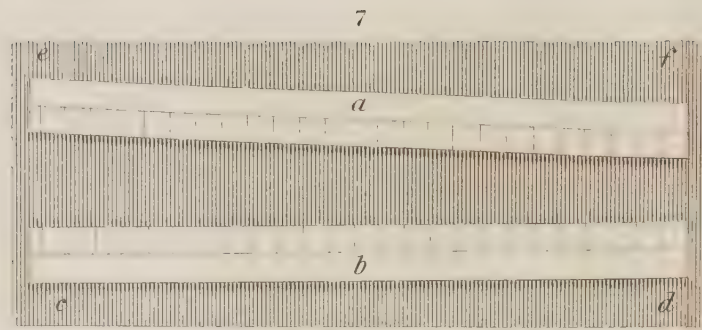
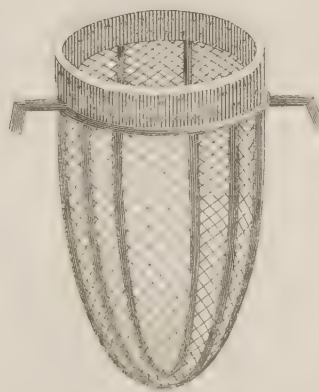
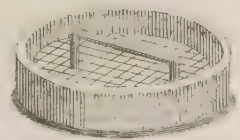
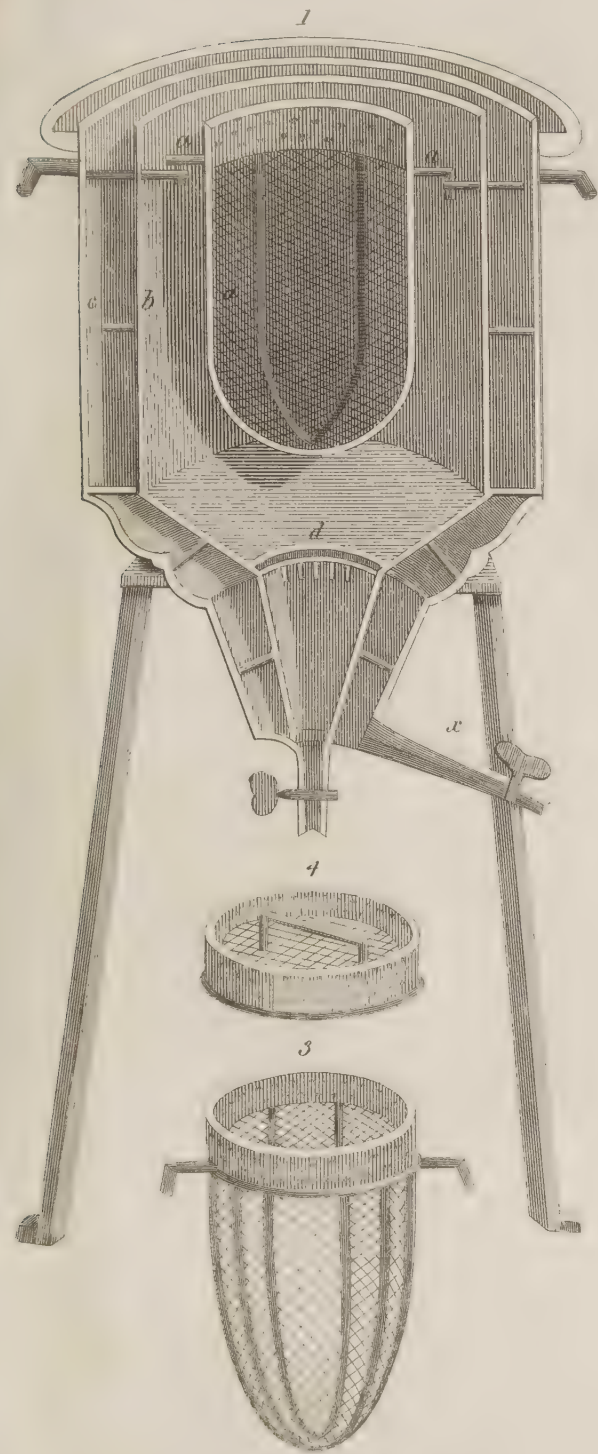












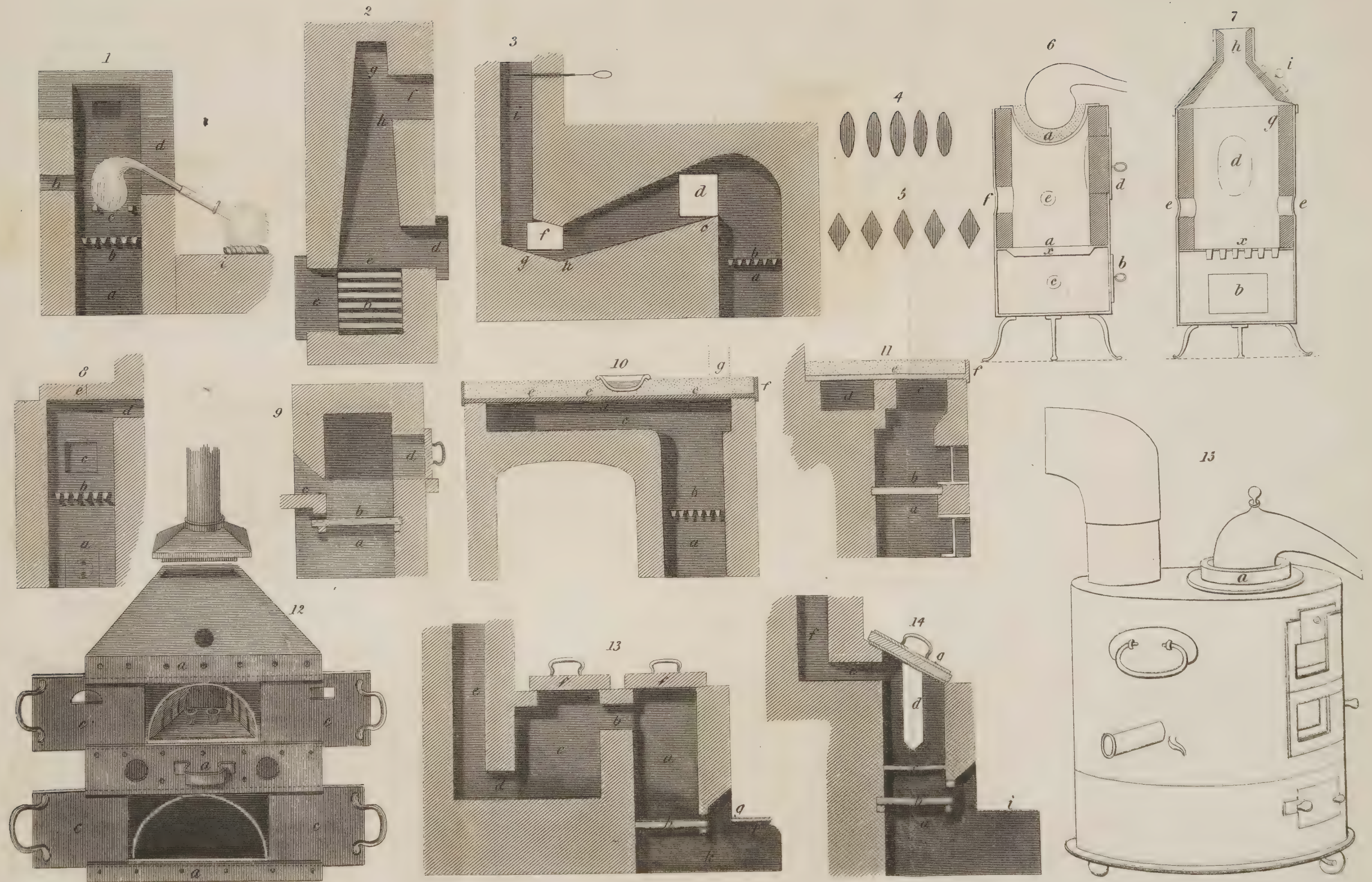




Fig. 1.

CHEMICAL	EQUIVALENTS.
Abbreviations.	10 Oxygen
d. Dry.	11 Water
c. Crystallized.	12
Ox. Oxid.	13 10 Hydrogen
Carb. Carbonate.	14
M. Muriate.	15
N. Nitrate.	16
S. Sulphate.	17 Phosphorus
W. Water.	18
	19
	20 2 Oxygen
	22
	24 Calcium
	26
	28 Sodium
	30 3 Oxygen
	32
	34 Iron
	36
	38 Phosphoric acid
	40
	42 Copper
	44
	46 Chlorine
	48 Muriatic gas
	50 Oxalic acid
	52 Sulphuric acid
	54 5 Oxygen
	56 Ox. Copper
	58
	60 2 Carbonic acid
	62
	64 6 Oxygen
	66 Oxid. of Vitriol
	68 (S. & L. 85)
	70 (d.) Nitric acid
	72 Strontia
	74
	76 10 Carbon
	78 Bi-carb. Ammonia
	80
	82 Sub-carb. Potash
	84 Liquid Nitric acid
	86 (S. & L. 90)
	88 Barytes
	90
	92 N. Lime
	94 N. Soda
	96 S. Potash
	98
	100 S. Strontia
	102 Bi-carb. Potash
	104 Lead
	106 Silver
	108 Litharge
	110 Ox. Silver
	112 Bi-oxal. Potash
	114 (60) Ox. M. Potash
	116 (c. 5 W.) S. Copper
	118
	120 N. Barytes
	122 Carbo. Sublimat
	124 Carbo. Lead
	126 S. Iron (c. 7 W.)
	128 M. Lead
	130 S. Zinc (c. 7 W.)
	132 Ovalute Lead
	134
	136 S. Lead
	138
	140 (c. 10 W.) S. Soda
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Fig. 2.

Fig.

2.

CHEMICAL

EQUIVALENTS.

Abbreviations

d. Dry.

c. Crystallized.

Ox. Oxid.

Carb. Carbonate.

M. Muriate.

N. Nitrate.

S. Sulphate.

W. Water.

Oxygen

Water

10 Hydrogen

Azote

Phosphorus

Sulphur

2 Oxygen

Ammonia

2 Water

Magnesia

Carbonic acid

Calcium

Nitric acid

Sodium

3 Oxygen

Muriatic acid (d)

Lime

Iron

Nitrous gas

Phosphoric acid

Soda

Copper

Zinc

Ox. Iron

Chlorine

Sub. Carb. Ammonia

Muriatic gas

Potassium

Oxalic acid

Red Ox. Iron

Sulphuric acid

Ox. Zinc

5 Oxygen

5 Water

2 Carbonic acid

Potash

6 Oxygen

Carb. Lime

Oxid. of Vitriol

Sub. Carb. Soda (d)

(S. & L. 85.)

M. Ammonia

(d) Nitric acid

M. Lime (d)

Strontia

S. Magnesia (d)

10 Carbon

7 Water

Bi-carb. Ammonia

S. Lime (d)

Sub-carb. Potash

S. Soda (d)

Liquid Nitric acid

M. Potash

(S. & L. 90.)

Bi-carb. Soda

Barytes

Selenite (2 W) c.

(d) N. Lime

10 Water

N. Soda

Carb. Barytes.

S. Potash

N. Potash

S. Strontia

M. Barytes (d)

Bi-carb. Potash

Red Oxid. &

Lead

S. Barytes

Silver

S. Magnesia (c. 7 W)

Litharge

N. Barytes

Ox. Silver

Carb. Lead

Bi-oxal. Potash

S. Iron (c. 7 W)

(60) Oxid. M. Potash

S. Zinc (c. 7 W)

(c. 5 W) S. Copper

Oxalate Lead

Corros. Sublimate

N. Lead

Phosph. Lead

Mur. Silver

S. Lead

(c. 10 W) S. Soda

2 Mercury

Coloured (2 &)

Protoid &

